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DUST EMISSION ON THE PREMISES OF THE PHOSPHORIC FERTILIZERS PLANT IN THE SEASIDE REGION

(Emisja pyłów na terenie zakładów nawozów fosforowych w regionie nadmorskim)

The atmospheric emissions occurring on the premises of a phosphoric fertilizers plant are characterized qualitatively and quantitatively. A modified Staplex-type apparatus developed was used in the dust concentration measurements. Computer-based analysis of the results obtained, with the use of Sutton's formula for the input data, enabled the rate of the emission index to be evaluated. Chemical analysis of the dust indicates that the fallout observed on the plant premises constitutes phosphate rock in 54.2%. The airborne particulate emissions instead contain those minerals in an amount of 49.4%. The methods of DTA and DTG and of microscopy were used to study the dust properties.

Chemical industry and the industry of building materials, next to mining, metallurgy, and power industry, are in Poland the major atmospheric polluters with both particulate and gaseous emissions. These emissions are generated during miscellaneous auxiliary operations such as weighing, screening, crushing, pulverizing, conveying, or transporting, as well as a result of the manufacturing processes themselves as waste products, intermediates, or products, which not infrequently may be a source of useful raw materials [1]. Essentially the air can be freed from contamination to any desired purity. This is only the matter of expenditure which rises pronouncedly with the degree of contamination. In order to find a suitable balance between the public health requirements and protection of the biosphere on one hand, and the expenditure on the other hand, threshold limit values should be known for individual pollutants, below which these pollutants have no deleterious effect on humans, animals, vegetation, as well as on building materials or metal structures. In the complex process of the protection of the atmospheric air the elimination of contaminants is the final stage. This stage is preceded by stages of determination of the emission rate, investigation of the properties of the effluent emissions,

analysis of meteorological and topographic data, city development projects, and the like. This data input is needed to make a preliminary decision as to the implementation of the most advisable and economically the most feasible method of the air pollution control.

In view of the increasing industrialization of the seaside region of Poland concerned and the expansion of freight handling ports, continuous monitoring of the air purity in those areas appears to be a necessity. Increased volume of freight handling of loose materials and large quantity of feedstock requisite for phosphoric fertilizers production pose a threat to the air quality of the atmosphere, and may adversely affect health of the inhabitants.

The aim of this study was to determine the rate of emission and the kind of the particulate emissions on the premises of the phosphoric fertilizer plant, with a description of the properties of the dust by chamical and physicochemical investigations, as well as the characterization of the dispersal of particulate emissions with a glance to meteorological data and localization of the plant. The study was made as a master of science dissertation at the Department of Technology of Inorganic Compounds of the Institute of Chemistry and Inorganic Technology of the Technical University of Gdańsk.

Location of the Plant

The phosphoric fertilizers plant is situated next to the brimstone yard and in the neighborhood of the shipyard. Farther west there is a heat power plant which handles substantial amounts of coal. From the northeast, the harbor facilities designed to handle coal and iron ore bulks. Eastwards there are brimstone handling facilities. The areas on which the plant premises are situated belong to the mouth of the Vistula River. The land is generally flat, and merely right on the seashore, stretches a narrow strip of dunes ten or so meters high above the sea level, at a distance of 2 km from the plant. In the south dense urban development begins.

Emission Rate and Dust Concentration of the Premises of the Plant

Measurements of the dust concentration over the premises of the plant in point were carried out in two independent series. In the first series use was made of the setup, widely accepted now in Poland, which incorporates a pump complete with a motor, a flowmeter, and a dust sampler [2]. The results obtained provide a picture of the atmospheric pollution on the premises of the plant under consideration (Table 1). All the data reported there refer to 24-hr measurements.

In compliance with the Decree of the Council of Ministers of September 13, 1966 (*Dz. U.*, No. 42, section 253), the concentration of a nontoxic dust should not exceed 0.2 mg/m³. The results gathered indicate that the standard was fairly often exceeded over the premises of the plant. The experimental series mentioned, even though it was carried out in conformity with the Polish standard, provided results that can be used merely to illustrate the current status of the atmospheric emissions rather than

Table 1

Dust Concentration Measurements Made with a Conventional Setup

Run No.	Dust Concentration mg/m³	Measuring site m	Phosphate fertilizer output tons/day	Wind direction			Wind speed m/sec			Deposit thickness mm
1	2	3	4	5			6			7
1	0.2019	(41.5; −78.1)	175.5	—	E	E	—	3	1	—
2	0.4721	(41.5; −78.1)	199.1	—	SSW	—	—	3	—	0.1
3	0.1860	(41.5; −78.1)	290.9	SSE	SSE	—	1	5	—	2.3
4	0.0328	(41.5; −78.1)	298.0	SE	E	SSE	2	2	3	—
5	0.0257	(41.5; −78.1)	123.0	N	N	NNE	1	1	1	5.0
6	0.0417	(41.5; −78.1)	275.0	—	NNE	—	—	3	—	0.6
7	0.0088	(41.5; −78.1)	217.0	N	N	N	1	1	3	7.3
8	0.1421	(41.5; −78.1)	157.0	—	—	—	—	—	—	—
9	0.3814	(41.5; −78.1)	132.0	WNW	N	NNE	5	9	—	—
10	0.0448	(41.5; −78.1)	164.0	SE	N	—	2	5	—	—
11	0.0648	(41.5; −78.1)	225.0	—	E	E	3	2	—	—
12	0.0039	(41.5; −78.1)	119.0	—	N	NW	—	5	3	1.9
13	0.2465	(41.5; −78.1)	208.0	—	NE	E	—	5	3	0.3
14	0.7006	(41.5; −78.1)	246.0	SW	WSW	W	3	7	3	0.8
15	1.2490	(−33.9; −33.9)	158.0	N	NNE	N	2	3	3	—
16	0.2364	(−33.9; −33.9)	122.0	N	N	N	1	1	2	—
17	1.8615	(−33.9; −33.9)	150.0	—	NNE	NE	1	2	1	—
18	2.6293	(−33.9; −33.9)	258.0	—	—	—	—	—	—	—
19	0.1432	(−33.9; −33.9)	319.0	—	NE	—	—	1	—	—
20	0.6480	(−33.9; −33.9)	214.0	S	NNE	—	—	1	2	—
21	0.5227	(−33.9; −33.9)	274.0	—	—	N	—	—	3	0.2
22	0.6760	(−33.9; −33.9)	212.0	SSE	S	S	3	5	4	—
23	1.1595	(−33.9; −33.9)	195.0	N	N	NNE	3	5	5	4.4
24	0.1387	(−33.9; −33.9)	236.0	NW	NNE	NNE	2	5	1	4.3
25	0.1926	(−33.9; −33.9)	343.0	E	E	ENE	5	7	—	4.0
26	0.3625	(−33.9; −33.9)	327.0	E	E	—	2	3	—	5.5
27	1.5256	(−33.9; −33.9)	285.0	SW	NE	N	1	3	3	—
28	0.0991	(−33.9; −33.9)	298.0	—	WSW	ESE	—	7	—	—
29	0.0810	(−33.9; −33.9)	231.0	NE	—	NE	1	—	2	—
30	0.0278	(−33.9; −33.9)	—	N	N	NE	—	2	1	—

Table 2

The Emission Rate Calculated for $d = 100$ m, $V = 2$–4 m/sec

Run No.	Run started time	Measuring site y, x	Actual wind direction	Actual wind speed m/sec	Wind speed assumed m/sec	Wind direction	Wind angle 0°/0′	Height of the emission source m	Distance from the source m	Dust concentration mg/m³	Coordinates of the measuring point x, y	Emission rate calculated g/sec	Average emission rate g/sec	Production output tons/day	Emission loss	
															%	g/ton
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
1	1:20 p.m.		W		1	0	0 0	20	100	.10	100.0	400.00 (0, 0)				
2	1:20 p.m.		W		1	0	0 0	20	100	.10	100.0	5.61* (0, 0)				
3	1:20 p.m.	(−100; 0)	W	2–4	1	0	0 0	20	100	.10	100.0	2.10* (0, 0)	2.69	154	0.151	1508
4	1:20 p.m.		W		1	0	0 0	20	100	.10	100l0	1.37* (0, 0)				
5	1:20 p.m.		W		1	0	0 0	20	100	.10	100.0	1.23* (0, 0)				

for forecasting purposes or for the input data in the computer-based calculations of the emission rate in that area of interest. For the latter purpose another series of measurements was performed using a setup designed after an American Staplex-type apparatus. The apparatus in question is much more efficient compared with the equipment hitherto employed. It is featured by a much higher air flow rate of 0.50 m³/min, whereas the pump incorporated in the previous type equipment yields only 0.0645 m³/min. The high air flow rate in the new apparatus accounts for a substantially shorter time required for a single run. Moreover, the new setup can be easily carried around, owing to which the measurements could be done along the wind direction at variable distances from 10 to 300 m from the major emission source. The dust collecting surface is 2.215 times larger than in the old-type apparatus. The filter, just like in the previous apparatus, was made of Whatman No. 1 filter paper.

The results obtained in the second series of measurements are listed in Table 2, where columns 6–13 represent the printout of the computer punched tape. In columns 1–5 are given: conditions, time, and place relative to a given measurement. In accordance with the scheme of the plant layout shown in Fig. 1, the coordinate system has been marked with the axes coincident with the cardinal wind directions: $N = -x$, $S = x$, $E = y$, and $W = -y$. The major emission source, which is ten exits of the exhaust and ventilation system of the milling plant, is located over a distance of

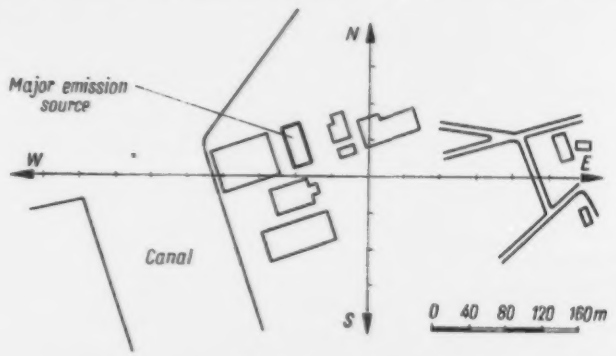

Fig. 1. Layout of the buildings of the phosphoric fertilizers plant.

55.3 m. As the middle of the emission of the entire fertilizers plant the center of the section mentioned was assumed (−67.7; — 36.9). Columns 14–16 provide the rates of the emission indices evaluated with computer.

The computer routine was developed using Sutton's equation in the transformation which permitted the calculation of the emission rate in terms of the concentration measurements

$$E = 0.5 \cdot S(y,x) \cdot \pi \cdot c_y \cdot c_z \cdot Vs_n \cdot x^{2-n} \cdot \exp \frac{Y^2}{c_y^2 \cdot x^{2-n}} + \frac{H^2}{c_z^2 \cdot x^{2-n}}$$

where

E — emission rate, g/sec,
s — concentration at the point (y, x), mg/m^3,
c_y — the diffusion coefficient in the direction y, m$^{n/2}$,
c_z — the diffusion coefficient in the direction z, m$^{n/2}$,
n — meteorological exponent,
H — height of the emission source, m,
Vs_n — mean wind speed at the height of the emission source, m/sec, [3], [4].

Column 8 was thought to be used for possible deviations of the wind direction from the axis of measuring point — emission point. The measurements reported in this paper were carried out under conditions of the overlapping of wind directions with the axes mentioned and, for that reason, the value printed by the computer is invariantly zero. A change was made in the routine in the coordinate system so as to make the emission coordinates (0, 0), whereas the concentration coordinates were (y, x). Subsequently, the following three conditions were added

$$y \leqslant [\tan(\beta/2)]x$$
$$z \leqslant [\tan(\beta/2)]x$$
$$x \geqslant H$$

where $\beta = 22.5°$.

Unless any of the above conditions was met, NTSW symbol was printed in column 13 which means that the measurement was conducted in a wrong sector.

Table 3

The Emission Rate Calculated from Sutton's Formula and from the Dust Concentration Measured under Known Weather Conditions

Run No.	Run started time	Measuring site y, x	Average g/hr	Production output tons/day	Emission loss	
					%	g/ton
1	12:50 p.m.	(80; 184.6)	0.37	258	0.017	123.90
2	10:43 a.m.	(40; − 40)	2.12	156	0.117	558.76
3	11:50 a.m.	(104.6; −104.6)	0.59	156	0.032	326.76
4	12:30 p.m.	(−95; 0)	6.44	154	0.362	3578
5	1:20 p.m.	(−100; 0)	2.69	154	0.151	1508
6	12:30 p.m.	(−95; 0)	6.44	154	0.362	3578

Table 4

The Emission Rate Calculated for $d = 9$ m, $V = 1$–3 m/sec

Run No.	Run started time	Measuring site y x,	Actual wind direction	Actual wind speed m/sec	Wind speed assumed m/sec	Wind direction	Wind angle 0°/0′	Height of the emission source m	Distance from the source m	Dust concentration mg/m³	Coordinates of the measuring point x, y	Emission rate calculated g/sec	Average emission rate g/sec	Production output tons/day	Emission loss	
															%	g/ton
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
1	11:25 a.m.		NNE		1	0	0 0	1	9	4.35	(9, 0)	.02* (0, 0)				
2	11:25 a.m.		NNE		2	0	0 0	1	9	4.35	(9, 0)	.04* (0, 0)				
3	11:25 a.m.	(30.7;83.0)	NNE	1–3	3	0	0 0	1	9	4.35	(9, 0)	.06* (0, 0)	0.04	258	0.002	13.39
4	11:25 a.m.		NNE		4	0	0 0	1	9	4.35	(9, 0)	.10 (0, 0)				
5	11:25 a.m.		NNE		5	0	0 0	1	9	4.35	(9, 0)	.13 (0, 0)				

The measurements were performed in rainless days at a wind speed ranging 1–5 m/sec — that is, under conditions prevalent over the area under discussion. The short time of the measurement (each run lasted for 20 min) ensured conditions of weather of insignificant variability. The emission rate was calculated as an average for the actual wind speeds. The calculated emission rates, which were used in subsequent calculations, are marked with an asterisk in the table. The average emission rates found permitted the evaluation of the emission indices for the known daily outputs of the plant. The rates obtained are featured by a rather considerable scatter which may be due to the following main reasons:

— differences in the vertical temperature gradient and the variations in the dust conveyance resulting therefrom,

— incorrect assumptions related to the production flow; not always the production rate calculated for a 20-min period based on the 24-hr data corresponds to the truth, for instance, not all the mills in the main milling department are operating in all the production cycles,

— the kind of the feedstock handled may be a controlling factor for the emission rate.

The emission indices calculated, and expressed in percent, ranged from 0.017 to 0.362%, which corresponds to an emission rate of 123.9 to 3578 g/ton of the feedstock ground (Table 3). Upon rejection of the extreme values, the average emission index obtained for the phosphoric fertilizers plant is 1.1 kg/ton of the rock phosphate ore processed. The measurements made indicate that the correct range of the distances from the measuring point from the emission source amounts to 50–200 m. For less distances the results obtained fall far off the average mentioned. The calculated emission index, for the measurements carried out very close to the emission source (9 m) (Table 4), amounts to 13.39 kg/ton of the ore handled.

Dust Fallout

Measurements of the dust fallout were performed with the aim to characterize the conditions of the atmospheric emission concentrations on the plant premises on a yearly basis. The measurements were made with consideration for the effect of the distance from the major emission source. Determination of the dust fallout consisted in the collection during a specified period of time of the dust settling in the collecting jars, followed by the measurement of its quantity gravimetrically [4], [5]. The collecting jars were hung at the points marked on the map (Fig. 2).

The dust fallout measurements were carried out on the premises of the fertilizers plant, in the coal and iron ore handling facilities, and in the shipyard.

In conformity with the Decree of the Council of Ministers of September 13, 1966, cited before, the dust fallout should not exceed 250 tons/km² annually.

The annual averages determined at the first eight measuring points spaced 250 m away from the major emission source, ranged 178.2 to 1827.8 tons/km² per year. The annual average from all the measuring points equals 627.2 tons/km² per year, which constitutes 250% of the accepted standard.

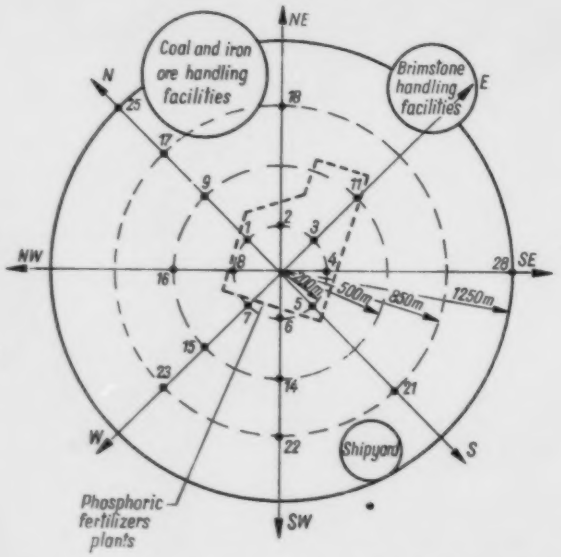

Fig. 2. Topography of sampling of the dust deposits.

The points of the highest fallout average occurred at distances 500 to 850 m from the source, and the annual average from all the points amounts to 295.4 tons/km² per year, which constitutes 118% of the standard value.

The coal handling facilities exhibited the least fallout, the annual average for the five measuring points located 500 to 1250 m away from the source being 92.5 tons/km² per year, which corresponds to 36.6% of the standard. Coal and iron ore were the majority of the emissions found, which is suggestive of the presence of some other emission sources in addition to the coal facilities.

To sum up, the size of the dust fallout depends to a considerable extent on the distance from the emission source and the location of the measuring point.

Microscopic Analysis of the Dust

The microscopic analysis made was aimed at determining the size of particles of phosphate rock, brimstone, and coal. The studies were carried out using an optical microscope. Magnifications employed were 500 and 1000 times. The dust size was determined by taking photographs upon which the measurements were directly taken [4]. The dust was characterized in terms of the effective diameter of dust particles, defined as the diameter of a circle whose surface area equals that of the projection of the dust particles [3].

The microscopic analysis of the dust fraction below 60 μm as obtained from sieve analysis provided the following values of the effective diameter for individual materials: for phosphate rock — 17 μm, for coal — 35 μm, and for brimstone — 56 μm.

Chemical Analysis of the Dust (Determination of Phosphate Rock in the Dust)

In the selected dust deposit samples, as well as in dust sampled from the air for the dust concentration measurements, phosphorus was determined colorimetrically with phosphomolybdate [6], [7].

Calculation of the phosphate stock and products from the phosphorus content is erroneous, as the dust analyzed is generated from the material of variable phosphorus content, notably from phosphate rock Morocco I and II with a P_2O_5 content of 30%, apatites containing a 39% P_2O_5, and superphosphate of a 45% P_2O_5 content. A mixture of these materials constitutes the dust under analysis. The phosphorus contained in the dust was expressed in terms of the most widely used feedstock for the manufacture of phosphoric acid and fertilizers, phosphate rock Morocco II. The results obtained indicate substantial variations in the composition of dust in the atmosphere in the neighborhood of the plants depending upon the wind strength and wind direction. The maximum content of the phosphate material in the airborne dust was 88.0% and in the dust deposit, 99.4%. The average content of the phosphate in the airborne dust was 49.4%, the corresponding value for the deposit being 54.2%.

The remainder of the dust components are largely coal particles originating from the nearby boilerhouse and the heat power plant, as well as the particles generated in the coal and iron ore handling facilities situated in the vicinity; silica- and brimstone-containing particles are also present in the dust.

Differential Thermal and Thermogravimetric Analyses

As already mentioned, the dusts under investigation consist primarily of phosphate rock and coal. For that reason separate analyses were made for individual phosphate rock and coal dusts and also for their mixtures. The DTA, DTG, and TG curves for pure phosphate rock dust are depicted

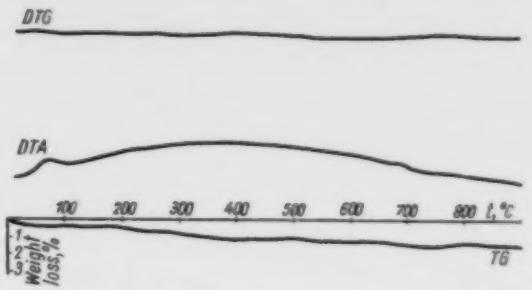

Fig. 3. Thermogram of pure phosphate rock dust: TG — 301 mg; TG sensitivity — 50 mg; DTA — 1/10; DTG — 1/10; heating rate — 10°C/min.

in Fig. 3. No evidence of thermal effects is found on the DTA curve but a tiny maximum, which may be responsible for trace carbonates or clay minerals present in the phosphate rock. Despite considerable sensitivity gained during the analysis, no energy or gravimetric effects are found on the DTA or DTG curves. The weight losses upon heating up to 1000°C are negligible and equal to 0.83%, and the process occurs at a practically equal rate. Pure phosphate rock dust tested underwent virtually no changes upon heating to 1000°C.

This is not the case, however, of pure coal dust. Its thermogram is shown in Fig. 4. A pronounced exothermal effect with a maximum at about 345°C is characteristic of the first stage of weight changes of the coal dust under study. The effect is due to the combustion of more volatile coal components. The next and quite appreciable exothermal effect with a maximum at 580°C corresponds to the process of coal combustion.

It follows from the TG curve that the first stage of the thermal decomposition is associated with evolution of the most volatile coal components. During that stage the sample loses 5.23% of its weight. In the next stage the weight loss proceeds more rapidly. However, as follows from the run of the TG curve, the process is not brought to completion up to 980°C (the temperature at which the analysis was finished). The weight loss during the combustion stage — that is, within the temperature

range of roughly from 500 to 980°C, it was 57.59%; the maximum weight loss was taking place at a temperature of 630°C, which corresponds to the maximum on the DTG curve (Fig. 4).

The appreciable differences in the runs of the analytical curves recorded for pure phosphate rock and coal dusts are useful in the analysis of mixtures of these dusts with the help of a differential thermal analyzer.

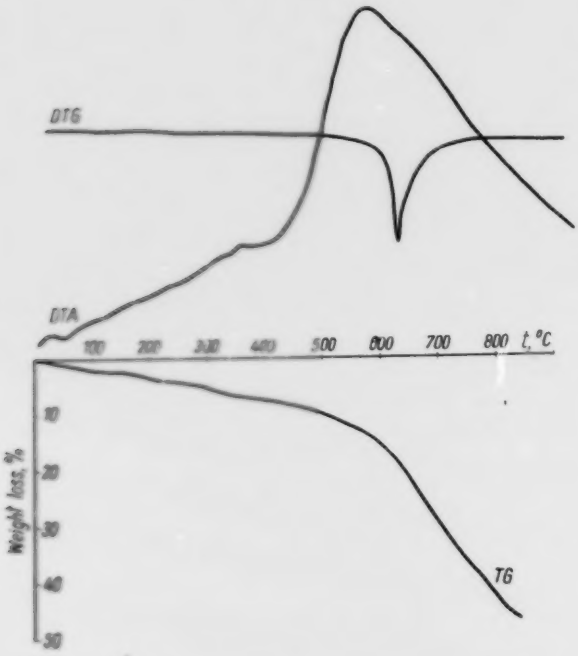

Fig. 4. Thermogram of pure coal dust: TG — 95.5 mg; TG sensitivity — 100 mg; DTA — 1/10; DTG — 1/10; heating rate — 10°C/min.

The characteristic data of the DTA and DTG curves for three samples of dust collected are listed in Table 5. To take an example, on a thermogram of sample No. 3 (Fig. 5) two exothermal effects are clearly visible on the DTA and DTG curves with maxima at 345 and 560°C. These maxima are responsible for thermal decomposition of coal dust. They are, however, lower than observed for pure coal dust, which is suggestive of that a mixture rather than pure coal is present in the sample considered. Likewise, a tiny maximum evident on the thermogram of pure phosphate rock dust and visible on the DTA curve recorded for the unknown indicates the presence

of carbonates or clay minerals there, as the maximum is absent on the thermogram of pure coal.

The data of Table 5 suggest that with lowering coal content paralleled by increase in phosphate rock dust in the unknowns the percent loss in weight, corresponding to the peculiar effects of thermal dec· ·position, becomes less. With lowering coal content also the areas conta··ed under the DTA curve diminish.

Table 5

Characteristics of the DTA and DTG Curves for Three Samples of Dust Deposits Collected

Run No.	Temperature of the 1st stage of thermal decomposition °C	The temperature at the max of the combustion effect °C	Weigh loss in the 1st stage of thermal decomposition %	Weight loss at the max of the combustion effect %	Total weight loss %
1	340	560	10.60	22.66	40.00
2	345	560	5.43	14.13	26.08
3	345	560	0.83	1.82	2.65

A quantitative evaluation of coal in the dust sample could be made on the basis of a graph of the percent weight loss up to 900°C against percent coal content (Fig. 6). As the coordinates of two points, required to draw a line, the following were assumed: at a weight loss of 0.83%, to pure phosphate rock dust corresponds no coal (0.00%), and to pure coal dust, at a weight loss of 50.26%, corresponds 100% of coal content.

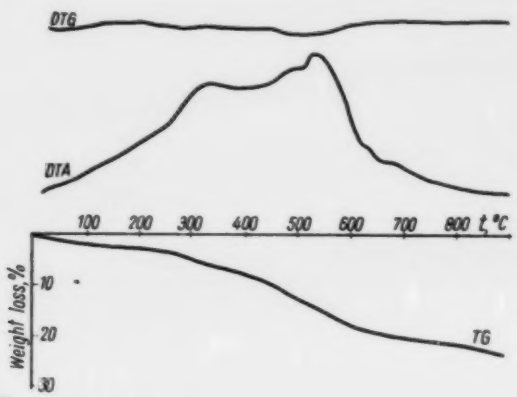

Fig. 5. Thermogram of a mixture of phosphate rock and coal dusts: TG — 92 mg; TG sensitivity — 100 mg; DTA — 1/10; DTG — 1/10; heating rate — 10°C/min.

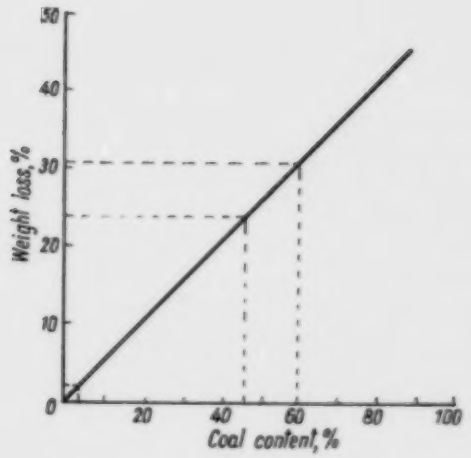

Fig. 6. Percent coal content in the samples of dust mixtures studied against the weight loss up to 900°C.

Conclusions

The dust fallout recorded on the premises of the phosphoric fertilizers plant amounts to an average 627 tons/km² per year, which is 2.5-fold above the accepted standard. In the adjacent shipyard the standard is exceeded by a factor of 1.18.

The dust concentration measured in 1971 on the premises of the plant exceeded the admissible standards in 50% of the measurements. The maximum concentration found in a 24-hr measurement on May 10, 1951 during calm and rainless weather was 2.63 mg/m³, which represented a 13.1-fold excess above the standards.

Approximately 50% of the dust determined in the particulate emissions on the premises of the phosphoric fertilizers plant constitutes phosphate rock dust; airborne dust average 49.4%, the deposit dust average 54.2%. The remainder of the dust components are primarily coal particles from the nearby boilerhouse and the heat power plant, as well as silica and brimstone particles.

The method of differential thermal analysis proved to be convenient for the determination of coal in the dust samples.

The microscopic method also employed enabled the determination of average values of the effective diameters of the phosphate rock particles (17 μm), coal particles (35 μm), and brimstone particles (56 μm).

For plants in which the majority of particulate emissions are discharged through stack or ventilation and exhaust holes, the most exact value of the total emission rate can be achieved in terms of direct measurements in the exhaust ducts and stack flues. This procedure is, however, unacceptable for the phosphate rock processing plants, where a large quantity of the particulate emissions are generated during the handling and in-plant transport, as well as from being blown out from the dumping grounds and from the plant premises (secondary air pollution with dust). Under similar circumstances the only feasible approach in evaluating the emission rate for the plant are the calculations in terms of Sutton's formula and of the dust concentration measured within the plant.

The average value of the emission index for the phosphoric fertilizers plant determined amounts to 1.1 kg dust per ton of the phosphate rock handled.

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ATMOSPHERIC POLLUTION MEASUREMENTS RESULTS COMPARED WITH THE AIR QUALITY STANDARDS

(Porównanie wyników pomiarów zanieczyszczenia atmosfery z normami jakości powietrza)

A quantitative method is advanced for comparison of results of the measurements of the atmospheric pollutant concentration with the air quality standards for any time interval. The quantitative criteria were derived using a mathematical statistics approach of confidence intervals. Two basic variants were considered: when the results obtained form a simple sample, and when they form a stationary time series. The empirical model due to Larsen in the US was adopted in comparison of the results of measurements of the pollutant concentration with the air quality standards. The objective of the study is to establish the guaranteed decision functions for the two cases of interest.

In the monitoring of the sanitary condition of the atmosphere, especially in urban agglomerations and industrial regions, of major significance is the comparison of the results of determination of the pollutant concentration with the air quality standards enforced by the regulations.

Whenever the threshold limit values for pollutants on a specific area are exceeded, and some preventive measures are to be taken, such as a limitation of the atmospheric emissions, certain quantitative criteria have to be developed to be used as a basis for decision making as to such a limitation, with a requisite guarantee.

Our treatment will be concerned with the questions related to the determination of a decision function guaranteed, on a confidence level assumed, for the cases when the air quality standards are and are not exceeded on a specific area and in the time of interest. Two variants are to be taken into consideration, notably:

— when the measurements results obtained form a simple sample,
— when they form a time series of a definite correlation radius.

Emission Concentration Data Which Form a Simple Sample

If the emission monitoring over a definite area is performed at suitably large time intervals, greater than the correlation radius of the time series, between successive measurements, or for mobile measurements when the instrument is continually changing its place, the data set obtained can be regarded as a simple sample — that is, it can be assumed that there is no autocorrelation in the time series thus achieved.

The Simple Sample When the Mandatory Air Quality Standards Are Exceeded

It is assumed that the emission concentration measurements are made with an averaging time of T_1, and that the results are to be related to the air quality standard concerning the same time interval. Furthermore, let the simple sample size (of the uncorrelated time series) be N and, according to the assumption, n measurements ($n \leqslant N$) exceed the air quality standard in force, Y_n, of a specific chemical pollutant.

In the case in point the guaranteed, on a confidence level assumed, decision function is equivalent to the lower estimation from the random sample of the probability of exceeding the standard. Since inequality $y \geqslant Y_n$ occurs with the empirical probability $p = n/N$, thus, if the following condition is fulfilled (cf. section 4.4 in [1])

$$\frac{N}{N+t(b)}\left(p+\frac{t^2(b)}{2N}-t(b)\sqrt{\frac{p(1-p)}{N}+\frac{t^2(b)}{4N^2}}\right) \geqslant K \qquad (1)$$

where

$t(b)$ — the abscissa of the Student's t distribution for $(N-1)$ degrees of freedom and a confidence level $(1-b)$,

K — the critical value of probability determined for a specific problem,

y — random variable; here any concentration of atmospheric emissions,

a preventive measure is taken over a given protected area as caused by the exceeded air quality standards, of an averaging time T_1, on the confidence level $(1-b)$ determined.

The current practice in Poland as to the interpretation of the threshold limit values for certain atmospheric pollutant chemicals admits the exceeding of, say, the mean 24-hr standard during a 5% of days a year ($K = 0.5$), and of the mean 20-min value during 0.5% of days a year ($K = 0.05$). Apparently, here the sample should be homogeneous in relation to the year's time, which is generally not fulfilled.

For a fixed measuring site, for instance, for 20-min concentrations the use of a so-called random sample proportionally stratified is of advantage [2]. In such a sample the initial element is randomly sampled from the first measuring 24-hr period, the next one, from the second 24-hr period but this time the element is not randomly sampled but it is shifted by a unit — that is, by the time of averaging of single observation, for example, $T_1 = 20$ min related to the time of the element already chosen, etc. The sample may also be made thicker by taking, for instance, k elements that are equidistant from the first 24-hr period, and on the next 24-hr period, all the elements would be shifted by a unit, etc.

The procedure adopted in the interpretation of the mandatory air quality standards, apart from being unintelligible for their common user — that is, the one not familiar with mathematical statistics, in the author's opinion, fails to ensure adequately the sanitary conditions of the atmospheric air in urban agglomerations. This is because under critical meteorological conditions of stagnant air, which usually last for a few days, the occurrence of abnormally high concentrations of atmospheric emissions is regular rather than occasional (random). On the other hand, it may also happen that the total of the stagnation spell at a definite site will be lower than 5% of days of the year, and then in compliance with the standing regulations there is no violation of the mandatory air pollution standards. Additionally, these regulations give no account of the degree of pollution hazard of the atmosphere during stagnation spells (every emission concentration value higher than the standard quantile of an order of, say, 5% is treated alike). Attention is called to the fact that in the United States, for instance, only the maximum values (that is, the extreme values of the random sample) are standardized for various times of averaging of the unit measurement, which are allowed to be exceeded at most once a year [3].

The Simple Sample of Not Exceeding the Air Quality Standards in Force

The situation of this kind occurs when one wants to be sure, on the basis of the results of measurements of emission concentrations, that at a specific site and time the air quality standards are not exceeded (with a guarantee on a definite confidence level $(1-b)$.

In the case under analysis the reasoning is concerned with the quantile lying above the extreme element of the sample. An assumption must therefore be made as to the kind of the statistical distribution of the population involved. For the measurements of the concentrations of atmospheric emissions it can be admitted that they form a logarithmic-normal distribution — that is, it is postulated that the transformed random variable

$$z = \log(y + C)$$

follows the normal distribution. To a first approximation it may be assumed that $C = 0$, and from the random sample of size N the distribution parameters can be evaluated from formulas

$$m = \frac{1}{N}\log(y_1 y_2 \dots y_N) \tag{2}$$

$$s = \frac{1}{N-1}\sqrt{\sum_{i=1}^{N} \log^2 y_i - Nm^2} \tag{3}$$

Subsequently, the order K of quantile $y(K)$ should be established, which in the statistical distribution under consideration cannot be greater than the mandatory air quality standard of the same averaging time as the measurements made — that is, T_1.

Under assumption that the air quality standards should not be exceeded at all in the measuring period concerned, it can be admitted that

$$K = \frac{T_1}{T} \tag{4}$$

where

T — the period of time in which the random sample was obtained.

If, on the other hand, a certain percentage of the time when the threshold limit values are exceeded is admitted, as discussed previously, $K = 0.05$, $K = 0.5$, etc.

On the basis of the assumptions made the following relations hold evidently

$$z(K) = \log y(K), \text{ and } Z_n = \log Y_n \tag{5}$$

where

Y_n — the standard threshold limit value (for the averaging time of the unit measuremenet, T_1).

Next, in accordance with sec. 4.7 in [1] and with a sufficient accuracy for the problem at hand, the dispersion of asymptotically normal distribution of quantile $z(K)$ of K order can be estimated from formula

$$s(K) = \frac{s}{\sqrt{N}}\sqrt{1 + 0.5t^2(K)} \tag{6}$$

where

N — the sample size,

s — the quantity defined by formula (3),

$t(K)$ — the abscissa of the standardized normal distribution for the value of the K ordinate,

and, upon rather trivial reasoning (covered at length in [2]), if the following inequality holds

$$Z_n > st(K) + m + s(K)t(a) \tag{7}$$

where

m and s — the quantities defined by formulas (2) and (3), respectively,

$t(a)$ — the abscissa of the Student's t distribution for $(N-1)$ degrees of freedom on the confidence level of $(1-a)$,

then on the confidence level

$$1-b = (1-a)(1-K) \tag{8}$$

it can be assumed (i.e., a decision can be taken) that the air quality standards are not exceeded (in the wording of definition (4) or of any other definition, e.g., $K = 0.05$, $K = 0.5$, etc.).

It will be noted that formula (8) is a corollary of the assumption of the independence of definition (4) (or else the definition that $K = 0.05$, etc.) and that the quantile of the distribution (5) was estimated by the method of confidence interval (with a dispersion (6) and a confidence level of $1-a$). The assumption appears to be natural as, for instance, in case the exact values of m and s parameters are known the following relation $Z_n > st(K)+m$ can be used instead of inequality (7), which occurs with a probability less than $(1-K)$. Since the confidence interval $(1-a)$ is independent of the reasoning adopted and may be taken arbitrarily, therefore, if it is admitted that

$$1-a = \frac{1-b}{1-K} \tag{9}$$

the auxiliary quantity a can be eliminated, and the interpretation of the results can be made with a requisite for the question under consideration guarantee — that is, on a confidence level of $1-b$.

Elaboration of the Results of Measurements of the Emission Concentrations Which Form a Correlated Time Series

Not infrequently the assumption of mutual independence of the results of the measurements of the emission concentrations entails too gross errors. This is the case, for instance, in interpreting the 24-hr mean emission concentrations obtained from continuous measurements during the year, as well as in working out the recordings of automatic instruments.

For stationary time series (i.e., such which form a dependent sample), such a series is best substituted by a simple sample of a hypothetical size of N_s which would be equivalent to that series as to the quantity of infor-

mation. To do this, the autocorrelation matrix of the series should be estimated, which is defined by relation

$$P = \begin{Vmatrix} 1 & r_1 & r_2 \dots r_k \\ r_1 & 1 & r_1 \dots r_{k-1} \\ r_k & r_{k-1} & \dots 1 \end{Vmatrix} \tag{10}$$

To a first approximation it may be admitted that the effective order of the matrix is far less than the series size (i.e., $k \ll N$) and the matrix elements can be estimated in terms of the point estimators from the general relation

$$r_w = r_{i-j} = \frac{1}{s^2}\left(\frac{1}{N-w}\sum_{i=1}^{N-w}\sum_{i=1+w}^{N} z_i z_j - m^2\right) \tag{11}$$

where

w — 1, 2, ... k,

m, s — as defined by formulas (2) and (3).

As demonstrated in earlier studies [1] and [2], the substitute size equivalent to a given series of the simple sample is obtained from formula

$$N_s = \frac{N}{1 + \frac{2}{k}\sum_{i=1}^{k-1}(k-1)r_i} \tag{12}$$

All the subsequent reasoning is identical with that developed for simple sample, and formulas (1) and (7) remain sound when the actual size of the series, N, is replaced by the substitute size N_s defined by formula (12).

Comparison of the Results of the Measurements of the Emission Concentrations with the Air Quality Standards of a Different Averaging Time

The concept of the air quality standard over the protected areas refers essentially to the atmospheric air which is used for respiration by communities (i.e., to the exclusion of the premises of working places). The threshold limit values adopted as standards, which were developed for relatively short averaging times of individual measurement (20 min to 24 hr), are meant to protect against acute diseases. With the chronic diseases in mind which result from atmospheric pollution, the monthly, seasonal, or annual standards should be established. On the areas particularly protected the threshold limit values for atmospheric pollutants should meet the same requirements but mainly in relation to vegetation which is often more sensitive to atmospheric emissions than human organism.

It follows from the above opinion that the results of determinations of the emission concentrations, carried out over the area of their activity with

respect to humans and vegetation, should be compared with the air quality standards established for various averaging time of individual measurement.

For a permanent atmospheric pollution measuring network equipped with continuous analyzers (e.g., of the coulometric type) the most adequate approach for the data processing is the use of the annual random sample proportionally stratified. If this sample constitutes a population of the elements of an averaging time T_1 equal, for instance, to 20 min, a relation is to be found which would enable the determination of the population parameters (time series) of the same physical phenomenon (i.e., the contamination of the atmosphere with a specified substance) but which was measured with different averaging times T_2 of individual measurement, e.g., 1 hr, 24 hr, etc. For this purpose use can be made of the empirical model of distribution of time intervals of the emission concentration measurements set forth by Larsen [3], [4] and substantiated theoretically in paper [2].

As explained previously, it can be assumed to the first approximation that the measurements of the emission concentrations over the protected areas, of any averaging time of individual measurement, yield logarithmic-normal distributions (i.e., the random variable $z = \log y$ has a normal distribution). Considering that between geometric mean m_g and mean geometric deviation s_g, on one hand, and the distribution parameters m and s as defined by formulas (2) and (3), on the other hand, the relation holds

$$m_g = e^m \tag{13}$$

$$s_g = e^s \tag{14}$$

then, on the basis of the relations derived at length in [2] and [3] the following expressions are obtained

$$m_2 = \ln\left[m\left(\frac{\exp m_1}{m_2}\right)^w\right] \tag{15}$$

$$s_2 = w^{1/2} s_1 \tag{16}$$

and

$$w = \frac{\ln(T/T_2)}{\ln(T/T_1)} \tag{17}$$

where

m_1 and m_2 — the average values of the logarithmic distributions of the atmospheric emission concentrations defined by formula (2), of the averaging time of a single measurement equal to T_1 and T_2,

s_1 and s_2 — dispersions of the logarithmic distributions of the emission concentrations defined by formula (3), of the averaging time of single measurement equal to T_1 and T_2.

m — the average value of the atmospheric emission concentrations (of any averaging time of a single measurement in the nonlogarithmic form),

T — the base reference period of Larsen's time model, commonly equal to one year (8760 hr).

To determine the decision function guaranteed on the confidence level of $(1-b)$ it was assumed that the concept of the log-normal distribution of the emission concentrations, inclusive of relations (15), (16), and (17) are strictly obeyed. Then, for the air quality standard of the averaging time of T_2 the following relations are derived using the method of confidence intervals and relation (6)

$$\log Y_a(T_2) < s_2 t(K) + m_2 - t(a)\frac{s_2}{\sqrt{N}}\sqrt{1+0.5t^2(K)} \tag{18}$$

— when the standards are exceeded on a confidence level of $(1-b)$, and

$$\log Y_a(T_2) > s_2 t(K) + m_2 + t(a)\frac{s_2}{\sqrt{N}}\sqrt{1+0.5t^2(K)} \tag{19}$$

— when the standards are not exceeded on a confidence level of $(1-b)$, where

N — the size of the original time series (of the averaging time of a single observation equal to T_1),

m_2 and s_2 — the quantities determined by relations (15) and (16) for point estimators (2) and (3) of the averaging time of T_2 of a single observation y_i; $i = 1, 2, 3 \ldots N$,

$Y_a(T_2)$ — the standard threshold limit value averaged for a time interval of T_2,

$t(a)$ and $t(K)$ — the quantities as defined in formulas (7) and (6).

Conclusions

On the basis of the above considerations the following major observations can be advanced, which may be of practical value for monitoring of the sanitary conditions of the atmosphere in large urban agglomerations:

1. Before any actions are taken to abate atmospheric pollution as well as during the very process of establishing the threshold limit values for atmospheric emissions, certain quantitative criteria have to be introduced to be used in decision making (i.e., short-term limitations of the emission by some manufacturing plants, putting into service the desulfurization process of flue gases in power plants, etc.). Such criteria are also expedient

in determining the total maximum number of days of a year during which the reduction of atmospheric emissions released will be necessary. The method of confidence intervals appears to be the most reasonable approach in comparing the results obtained with the air quality standards, when a suitably ample and representative experimental data for the atmospheric emission concentrations over an area of interest has been collected. This method provides the desired quantitative criteria expressed by formulas (1), (7), (18), and (19).

2. If a sufficiently long time series is available (i.e., the random sample has been obtained over an extended period of time), the random sample proportionally stratified is preferred along with the following quantitative criteria: (1) if the mandatory air quality standards are exceeded, and (7) otherwise.

3. If a maximum use has to be made of the information contained in the time series, the substitute size of the series should be first estimated as defined by formula (12) prior to the use of quantitative criteria (1) or (7). The computations can be efficiently made merely by the electronic computer technique in current use today.

4. It is essential in the monitoring of the sanitary conditions of the atmosphere to compare the measurement results obtained (measurements of the emission concentrations) with the air quality standards which were obtained for various averaging time. The experimentally verified Larsen's model is recommended along with the quantitative criteria (derived by the method of confidence intervals) defined by expressions (18) or (19) if the air quality standards obtained for a different averaging time of a single measurement compared with the original time series are exceeded or otherwise, respectively.

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THE CUPOLA EMISSION CONTROL BY WET TECHNIQUES

(Oczyszczanie gazów żeliwiakowych metodami mokrymi)

Discussion of the requirements from the cupola exhaust control systems with the results of studies on wet control systems and suggestions as to the solution of design problems involved in the use of wet mechanical emission control devices.

The control of the cupola furnace emissions offers a separate problem of the environment protection in foundry practice. Economically sound solution of this problem calls for a detailed analysis of the furnace processes and a knowledge of the emission rate of particulate and gaseous contaminants.

The cupola emissions consist of dust and gaseous components as SO_2, H_2S, fluorine compounds, and not infrequently even the volatile matter produced during combustion of oil scrap iron. The dust emission there depends to a large extent on the way the furnace process is run and, additionally, on the kind of coke used (traditional or molded sort), the condition of the furnace lining, the kind of blast and the charging technique employed.

Specifically, molded coke is featured by a higher dust formation than traditional coke, and the dust emitted is of higher density and is finer than that from the latter. Preheated blast, however, decreases the dust emission and its density but, at the same time, its fineness increases. The average emisson rate index for dust contaminants from cupola furnaces ranges 4.5 to 7 kg/ton of gray iron, the value for gaseous contaminants being 2 to 5 kg/ton of gray iron. Moreover, carbon monoxide present in the cupola exhausts is discharged through the cupola shaft into the atmosphere. The CO content in the exhausts ranges 5 to 12 or even up to 15%.

Even though the particulate and gaseous emissions from the cupola furnaces are discharged at a relatively low rate, the kind of the emissions released offers a considerable hazard for the crew and the environment. For that reason every project related to the construction or modernization of

cupola furnaces should involve the use of the emission control equipment suited to the unit size and to the available conditions in the industrial plant.

For moderate-size cupola units of a capacity of 3 to 4 tons per hour the stationary control devices are often economically unsound. In such cases, in view of a fairly low emission rate of contaminants of the kinds mentioned, wet hoods of a suitable design provided over the elongated cupola shaft combined with simultaneous afterburning of CO at the charging door level were found adequate.

For cupolas of a larger capacities of over 5 tons per hour the control systems are preferably built so as to serve several furnace units, and their efficiency is suited to the expected rate of emission of particulate and gaseous pollutants. The use of high efficiency devices is economically sound, and the measures to eliminate deleterious contaminants as carbon monoxide, hydrogen fluoride, and sulfur dioxide are highly commendable for large capacity cupolas in excess of 10 tons per hour.

The Requirements from the Cupola Emission Control Systems

The requirements imposed on the emission control equipment result primarily from the air pollution control legislature that varies from one country to another. In the majority of Western countries the permissible emission rate of particulate and gaseous contaminants is related to the capacity of cupolas and to their operation period throughout the year. In the Soviet Union and Czechoslovakia the regulations of the sanitary authorities provide a maximum dust concentration in the discharged gases of 100 mg/m³. Instead, our legislature specifies the ground level concentration of dust and gaseous emissions in the vicinity of the foundry. For that reason the designer's efforts were aimed toward simplest devices with simultaneous emphasis on topographic conditions, emission background values in the area of localization of cupolas, and the stack height. Generally the requirements related to the dust concentration of the cupola exhaust gases can be subdivided into moderate, i.e., of the emission index larger than 1.5 kg dust per one ton of product, which corresponds to a dust concentration above 1 g in 1 m³ gas, medium, with an emisson index 0.6–1.5 kg dust/ton of product, i.e., 0.4–1.0 g dust/m³ gas, and high, corresponding to a quantity of up to 0.15 kg dust per one ton of product, and a dust concentration below 100 mg/m³.

While at moderate emission rates, i.e., at values in excess of 1.5 kg dust per one ton of product, simple control devices can be used, such as wet hoods or multicyclones or cyclone batteries, even at medium rates medium-resistance wet collection devices have to be resorted to, like rota-

ry scrubbers, contact scrubbers, sparger scrubbers, or dry electrical precipitators.

The high requirements instead call for the control equipment of a collection efficiency above 98% thus relatively expensive one, such as high-efficiency bag filters or electrical precipitators of the wet type or else wet collection devices which incorporate a Venturi coagulators of a fairly high operating costs.

The solution adopted should therefore maintain the proper proportion between the outlay for the air pollution control and the manufacturing costs.

Afterburning of the Cupola Exhaust Gases

Of major significance for the treatment of the cupola exhaust gases is the manner in which they are captured. One of the way of rendering these gases less harmful is the afterburning of CO. Complete combustion of CO for the wet control equipment improves efficiency of the emission

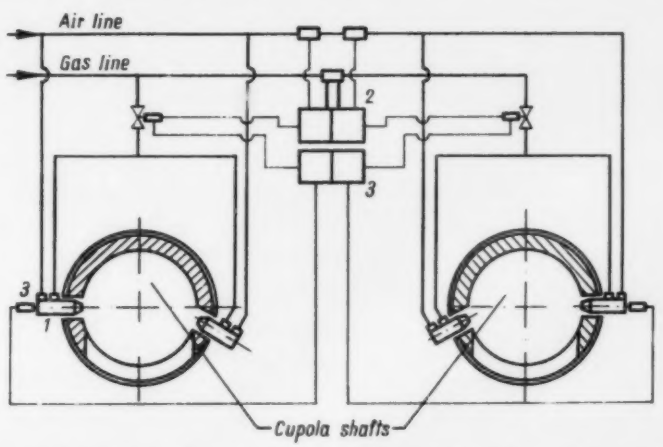

Fig. 1. The CO afterburner plant provided in the cupola stack: *1* — burner; *2* — automatic emergency cutoff valve, which shuts off the gas line in cases of the gas pressure disappearance or discontinued electric power supply; *3* — the photoelectric flame sensor.

control devices, solves the problem of ventilation in the cupola house and of the hygiene at work. The tests and investigations conducted in this country on the efficiency of afterburning and its effect upon the emission control process demonstrated that the combustion of gases containing CO in a quantity of 11 to 12% and a humidity of 80 g per kilogram of gas

can run at a temperature of 600°C. At a lower combustion temperature ($\leqslant$ 400°C) the CO content in the gas should not be lower than 15%, whereas a further decrease in temperature from 400°C to 200°C requires for their afterburning at least 25 to 27% CO in the cupola exhaust gases.

Considering the variable operating conditions of cupolas and the gas temperature changes over a range of 200 to 600 or even to 800°C, which is particularly true of the gases vented through the cupola shaft, and which is also due to the break in the top flame during the charging operation of the cupola, the solution that provides the CO afterburning with the help of the pilot flame fails to yield desirable results.

As demonstrated by the tests performed at the "Opam" Air Pollution Control Equipment Designing and Delivery Enterprise, the only safe systems appear to be those in which the gases are burned upon their previous enrichment with the burners suitably provided in the cupola shafts, and in the case of gases vented to the heat exchanger, in the section before the exchanger (Fig. 1).

The CO afterburner system, shown in Fig. 1, operates automatically. The burners of the turbulent or the liquid-fuel types equipped in the region of the charging door are remote controlled and are provided with automatic safety devices. This system has for the first time been introduced in this country on commercial scale in cooperation with the Cracow Designing Division of "Prodlew" Enterprise.

A Brief Review of the Cupola Emission Control Techniques

Of a wide variety of available methods of control of the cupola emissions wet techniques have gained acceptance largely on account of 3- to 5-fold lower prime cost compared with electrical precipitators and fabric filters and much smaller size of the control units. However, the major advantage of the wet control techniques is that both particulate and gaseous emissions can be trapped in one operation. Whenever gaseous contaminants are to be treated in the systems based on the use of dry electrostatic precipitators of fabric filters, such devices have to be followed by special equipment. The fabric filters additionally offer an operational hazard due to low resistance of the filter fabrics produced in this country to sulfur compounds and to the condensing volatile impurities produced from the scrap metal that is often oily. If CO has not been completely burned, the use of fabric filters is connected with fire hazard as the gases are liable to ignite.

If the dry electrical precipitators are used, the troublesome operation observed is mainly due to condensation of volatile matter, generally tar, on the electrode surfaces. Furthermore, electrical precipitators may only

be used when outmost care is taken to prevent the access of an explosive mixture. The means of the dust emission control in cupolas widely used until recently in our foundries were spark arresters equipped atop of the cupola shaft, which were also a fire-preventive measure. A relatively low efficiency of spark arresters prompted designers to their modernization to achieve a possibly high dust collecting efficiency. Increased collection efficiency was accompanied by an elevated resistance to gas flow, which in turn required the stack draft to be stronger. Should the pressure drop be too large, then part of the gaseous emissions should be vented to the cupola bay through the charging door creating thereby the carbon monoxide poisoning hazard for the cupola crew. Well operated wet hoods developed from spark arresters attain 55% efficiency (dust collection index of 1.5 to 4.5 kg dust per one ton of product) and thus they can be merely used on low capacity cupolas and for low emission rate of gaseous and particulate effluents.

Dust Collection Mechanism of Wet Mechanical Emission Control Devices

For illustration in Tables 1 and 2 are given chemical composition of the gas and particle size distribution of the dust discharged from a cupola

Table 1

Chemical Composition of the Cupola Exhaust Gas

Composition	Cupola stack %	Hot blast stove stack %
CO_2	12.4	3–8
O_2	8.6	11.8–17.5
CO	none*	0.0–0.2
N_2	remainder	remainder

*After combustion of CO in the afterburner

Table 2

Grain Size Analysis of the Cupola Exhaust Dust

Range μm	Cupola stack %	Hot blast stack %
0–5	5.0	8.0
5–10	2.0	22.0
10–20	5.0	23.5
20–40	10.0	23.0
40–60	5.0	9.5
60–100	20.0	5.5
100–200	10.0	8.5
>200	43.0	—

furnace working with preheated blast and a CO afterburner according to the measurement data collected at the Katowice "Opam" Enterprise.

As seen from Table 2 the dust present in the cupola exhaust gas, even though it does not contain a high percentage of the fine-grain fraction, offers a certain problem with separation of that fraction.

As the result of extensive research conducted in this country for the recent years it has been learnt which mechanisms are responsible for, or at least favorably affect the dust collection process. This process depends on the furnace process and the kind of charge used. It is known that the products of incomplete combustion of oil not infrequently present in the charge yield inhomogeneous coagulates with dust particles and the entities are of like electric charges.

Separation of fine fractions of such dust from the gas necessitates the use of relatively high kinetic energies which result in mechanical abrasion of the particles owing to a drastic pressure drop accompanied by diffusion and coagulation mechanisms. This is accomplished with the help of Venturi-type coagulators, which belong to dynamic wet scrubber class of equipment.

The dynamic wet collection with the use of rectangular cross-section Venturis is particularly attractive with respect to the way water is fed for the coagulation process. The water spray is generated in such devices by first bouncing of the water jet coming from the nozzles against the chamber wall and, subsequently, in the throat by the gas jet of a high velocity. Similar design is featured by the elimination of spray nozzles which are troublesome in service as they often get clogged, by saving in the water pressure and, above all, by affording a complete coverage of the Venturi throat, which is not always the case of the round cross-section Venturis in the multiventuri systems.

The on-line testing of the wet collection devices was conducted by "Opam" Enterprise originally on a pilot scale and later on a commercial one.

The Pilot Plant

The gases vented through the cupola stack above the charging door and from the heat exchanger stack were combined and delivered onto the test collection plant composed of the following units:

— gas cooler (a foam scrubber) of a capacity $V = 4500–5000$ m³/hr and a pressure drop $\Delta P_{max} = 150$ kg/m²,

— a round cross-section Venturi of a capacity $V' = 5000$ m³/hr at a pressure drop $\Delta P_{max} = 820$ kg/m² and a gas velocity in the throat ranging 80–100 m/sec,

— a rectangular cross-section Venturi of the Kinpactor type of a capacity $V' = 5000$ m³/hr and a pressure drop $\Delta P_{max} = 820$ kg/m² at a gas velocity in the throat 80 to 100 m/sec,

— an impingement scrubber of a capacity $V' = 5000$ m³/hr and a pressure drop $\Delta P_{max} = 250$ kg/m²,

— a foam scrubber of a capacity $V' = 4500$–5000 m³/hr and a pressure drop $\Delta P_{max} = 150$ kg/m² equipped with two grate beds and a demister,

— two MWW-18 fans connected in series of a capacity $V' = 5000$ m³/hr and a pressure $\Delta P = 650$ mm H_2O,

— a water pump of a delivery $V' = 8.5$ m³/hr and a delivery head $H = 67.5$ mm H_2O.

The temperature of the mixed gases from the afterburner was 250 to 350°C, whereas that of the gases taken from the cupola stack ranged 500 to 900°C. In Fig. 2 is shown a schematic diagram of the pilot plant. In foam scrubbers the process of precipitating the dust particles from the contaminated gas takes place under vigorous turbulence of the binary gas-liquid system. The dust precipitated passes into the liquid in the tank and is gradually settling on its bottom wherefrom it is removed by the sludge disposal system.

The scrubbers were operated under closed water circulation, i.e., water was supplied by the pump from the water tank through the distributor onto the grates.

In the impingement scrubber precipitation of dust particles from the dust-laden gas occurs when the dust jet is allowed to impact at a high speed on the water surface. To prevent the nozzle from being clogged, the nozzle is provided with a flushing system supplied with clean water. Both the Venturi scrubbers applied differ in design and in the way the water is fed to coagulate the dust. In the round cross-section Venturi water is fed axially by means of a nozzle-type distributor, whereas in the rectangular cross-section type water is delivered tangentially by two distributor chambers jointed by welding to the side walls of the constriction and of the confusor.

Results of tests carried out on the pilot plant were helpful in the selection of suitable devices for the commercial-scale plant and in the determination of optimum operational parameters of these devices in controlling the cupola exhaust gases.

The Commercial-Scale Plant

The commercial-scale plant handles all the exhaust gases discharged from an alternately operated cupola battery and from the associated hot blast system. Emission hooding systems are below the wet hoods of cupola

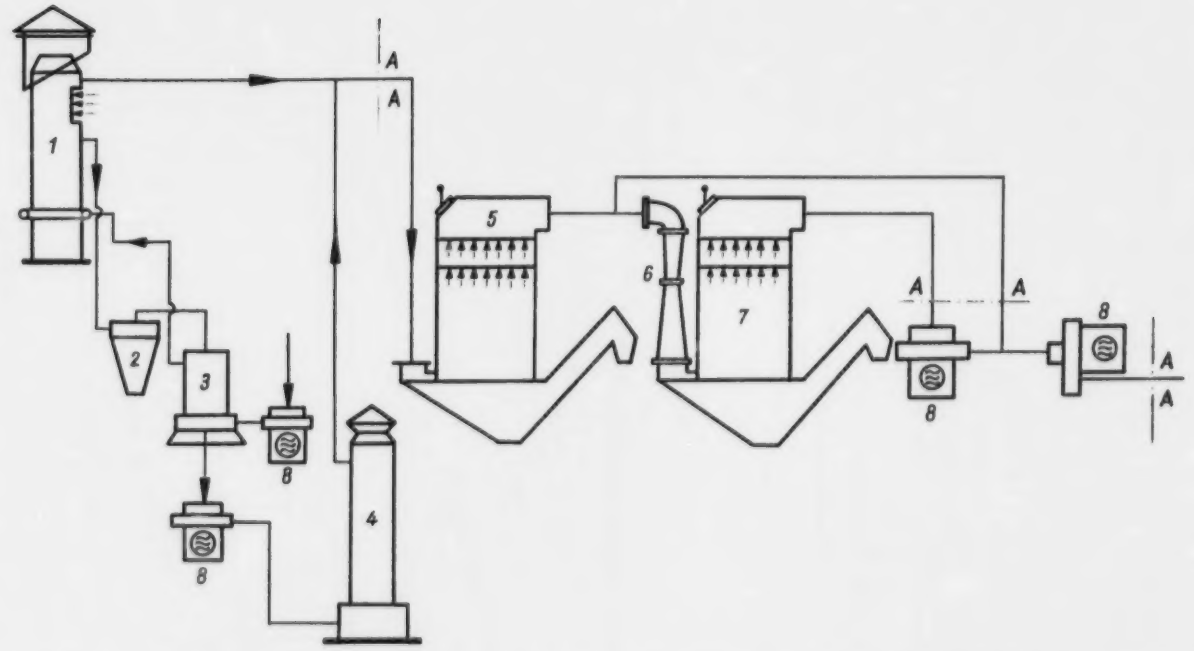

Fig. 2. Schematic diagram of a pilot plant of a cupola emission control system: *1* — cupola, 1400 mm in diameter; *2* — cyclone collector; *3* — heat exchanger provided with an afterburner; *4* — hot blast stack; *5* — cooler; *6* — Venturi tube; *7* — foam scrubber; *8* — fans.

stacks and hot blast stack. The gases picked up from the hot blast system are precleaned and afterburner-treated to remove carbon monoxide present.

The commercial-scale cupola emission control plant is depicted schematically in Fig. 3. The emissions produced in the cupola shafts are controlled by afterburning without precleaning by means of the burners provided at half of the height of the charging door. The emission hooding system is equipped with bell valves which ensure a tight sealing of the system from the emission control system. The valves, which are manually or remote controlled, are interconnected electrically with suitable stack dampeners. A typical industrial plant for the cupola emission control for a cupola system of a capacity of 15 tons per hour incorporates the following units:

— gas cooler of a rated capacity V = 65,000 to 70,000 m³/hr and a pressure drop ΔP_{max} = 100 kg/m²,

— multiventuri collector which consists of four Venturi tubes and two foam scrubbers, of a capacity from 65,000 to 70,000 m³/hr and a pressure drop of 550 to 850 kg/m²,

— draft fan of a rated capacity V = 70,000 m³/hr and rated pressure ΔP = 950 to 1050 kg/m².

The dirty water from the dust control system is gravitationally removed through sludge pipes to the granulate settling tank and, subsequently, pumped over into the slurry and water utilization tank. Upon purification and neutralization water is fed through a master pipeline to the control plants. The recirculated water delivery rate fed to the plants is 180–230 m³/hr. Results of the tests carried out on the commercial-scale plant are collected in Table 3.

The results show that of a total of five control systems examined merely the rectangular Venturi system ensures purification of the cupola effluents from dust down to a value below 100 mg/m³. That high degree of purification has been accomplished for a water delivery rate of 4.2 l/m³ of the exhaust gas. For the quantity of water used the average dust concentration of the gaseous effluent was about 46 mg/m³ (STP), whereas the pressure drop across the Venturi was 800 kg/m².

The results obtained for a three-stage dust control system with a round cross-section Venturi tube fail to provide so high a degree of purification of the exhaust gases as the previous one, since the dust concentrations downstream of the control system are on the average 130 mg/m³ (STP). The values are lower than those attained for the impingement scrubber system. All the same the system appears to be unsuited for the medium requirements as to the emission control in view of the fact of a rather appreciable horsepower used up by the round Venturi system.

The satisfactory results of operation of the pilot plant have prompted

"Opam" Enterprise to embark upon the project of a large-scale plant for a cupola emission control plant for cupolas of a capacity of 15–17 tons gray iron per hour.

Table 3

Results of Measurements of the Commercial Plant

Characteristics	Unit	Results	
Flow rate of the exhausted gases	m^3/sec	28.75	32.3
	m^3(STP)/sec	11.15	11.85
Flow rate of the gases downstream of the fan	m^3/sec	17.25	15.8
	m^3(STP)/sec	14.35	13.1
Average temperature of the exhausted gases	°C	427	475
Average temperature of the gases after the plant	°C	56.5	56.0
Average dust concentration of the exhausted gases	g/m^3(STP)	1.46	1.21
Average dust concentration of the gases after the plant	g/m^3(STP)	0.069	0.077
Resistance of the Venturi coagulator	N/m^2	8260	8300
Resistance of the emission control plant	N/m^2	8949	9288
Efficiency	%	94	93.5
Dust emission rate into the atmosphere	g/sec	1.0	1.01
Moisture content	g/m^3	60	79
SO_2 concentration	g/m^3	0.2	0.32
SO_2 emission rate into the atmosphere	g/sec	2.87	4.2
Water consumption: coolers	l/m^3 of gas handled	1.68	2.1
coagulators	l/m^3 of gas handled	1.90	1.73
scrubbers	l/m^3 of gas handled	0.68	0.78

The measurements on the industrial plant were carried out during the period of normal operation of the cupola. The average dust concentration downstream of the control system was about 70 mg/m^3 (STP). This value was achieved for a water delivery rate of 1.7–1.9 l/m^3 of the gas cleaned at a pressure drop across the plant of 900 kg/m^2. The particulate emission rate from the cupola upon treatment of the exhaust gases was 3.6 kg/hr, whereas the SO_2 value did not exceed 12 kg/hr.

On the basis of investigations and measurements on the wet cupola emission control systems typical systems have been developed at the "Opam" Enterprise for cupolas of various capacity and diversified requirements as to the emission control efficiency. Each of those systems operates with an automatic control and safety lines and is remote controlled from a central control room. All the drives are remote operated from the control room where the control and recording instruments have been located.

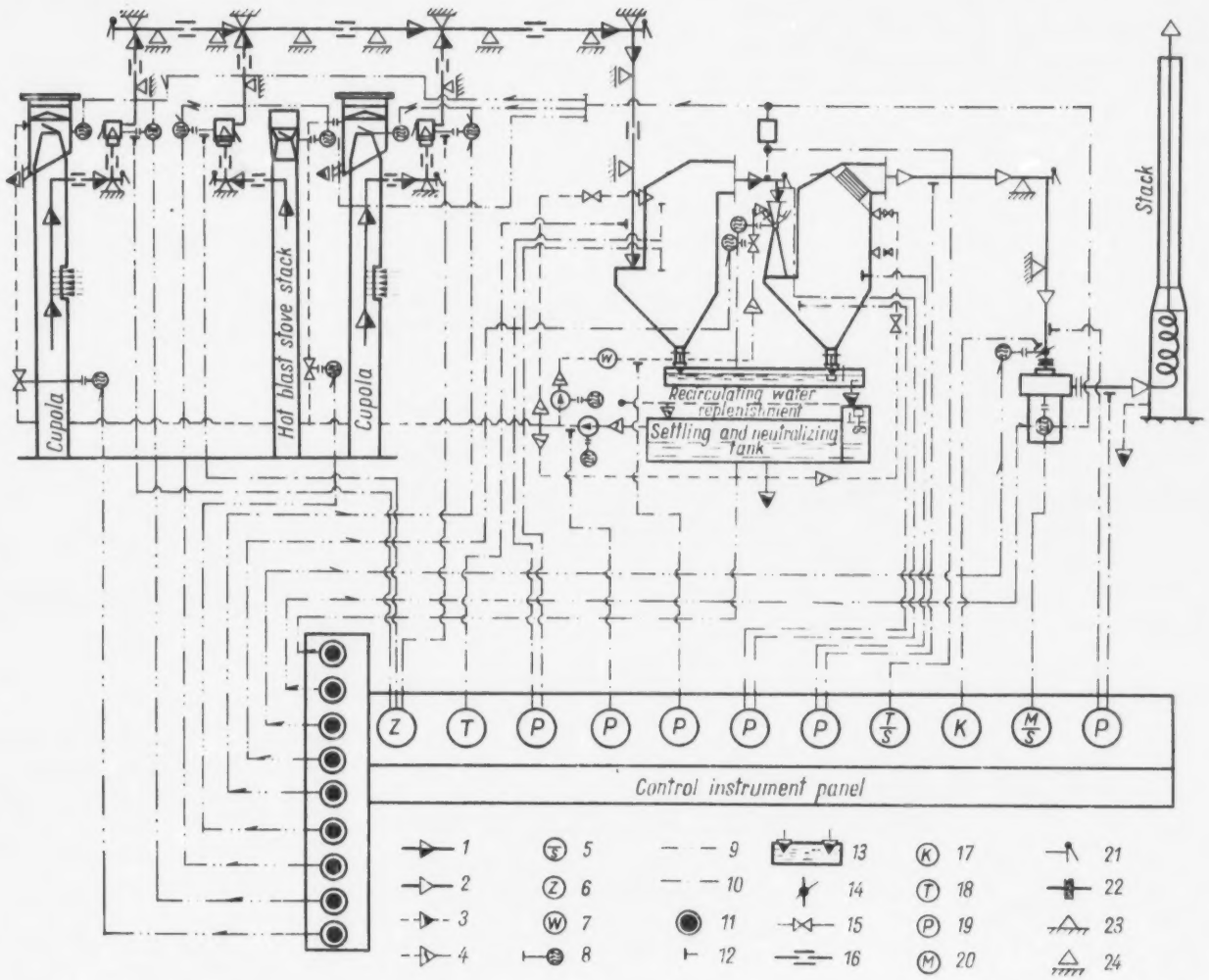

Fig. 3

Fig. 3. Schematic diagram of the Venturi-type wet collection system for the cupola emission control: *1* — dirty gas; *2* — cleaned gas; control pulse; *10* — measurement pulse; *11* — control button; *12* — sensor; *13* — hydraulic seal; *14* — damper; *15* — valve; *16* — expan *22* — flexible pipe joint; *23* — fl

Fig. 4. Schematic diagram of the cupola emission control system with the use of

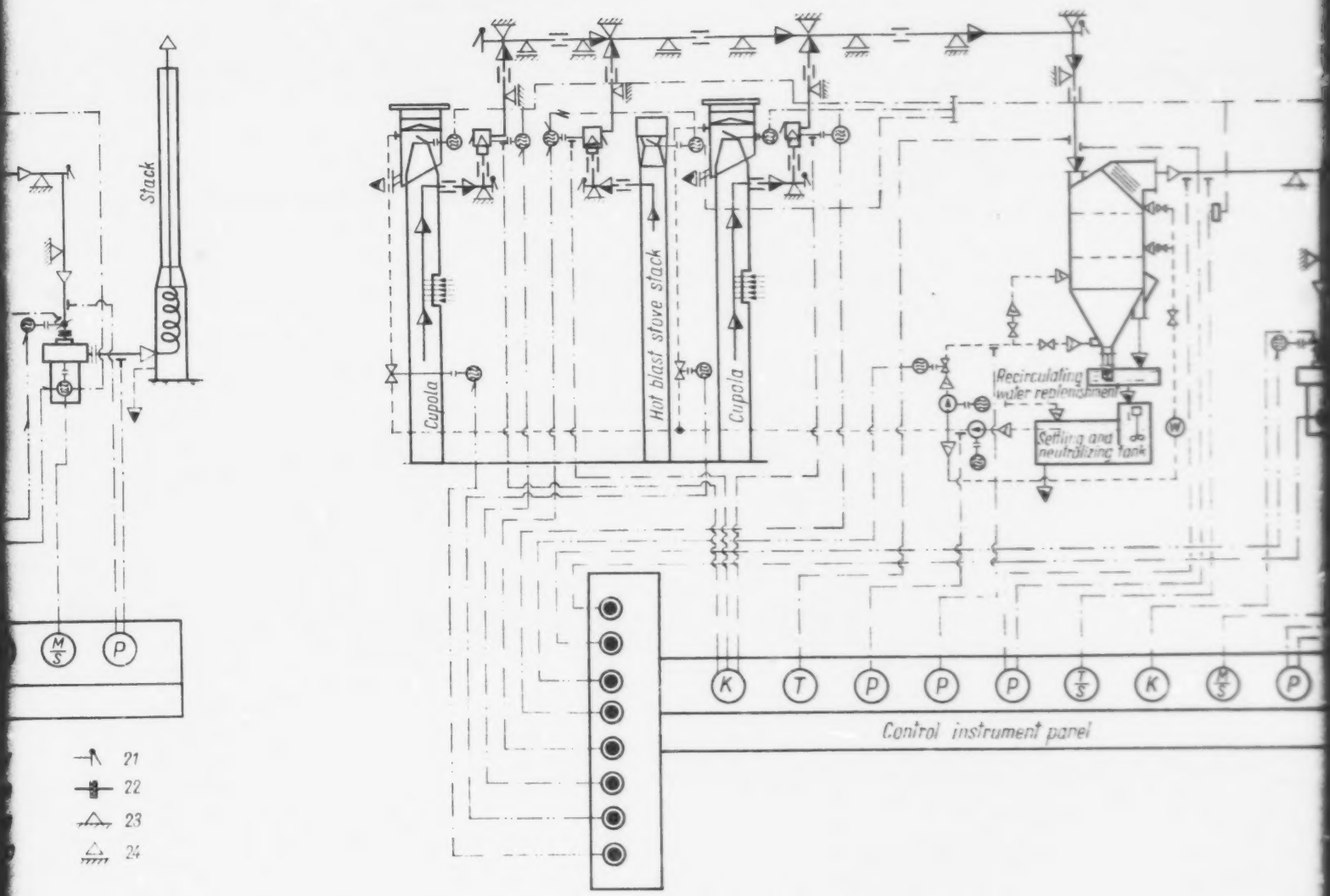

Fig. 4

1 — dirty gas; 2 — cleaned gas; 3 — dirty water with sludge; 4 — cleaned water; 5 — alarm signal; 6 — open-closed signalization; 7 — water flow gage; damper; 15 — valve; 16 — expansion joint; 17 — closed position indicator; 18 — temperature gage; 19 — pressure gage; 20 — power consumption gage, 22 — flexible pipe joint; 23 — fixed bearing; 24 — movable bearing.

ion control system with the use of a medium-resistance contacting scrubber (notation as in Fig. 3).

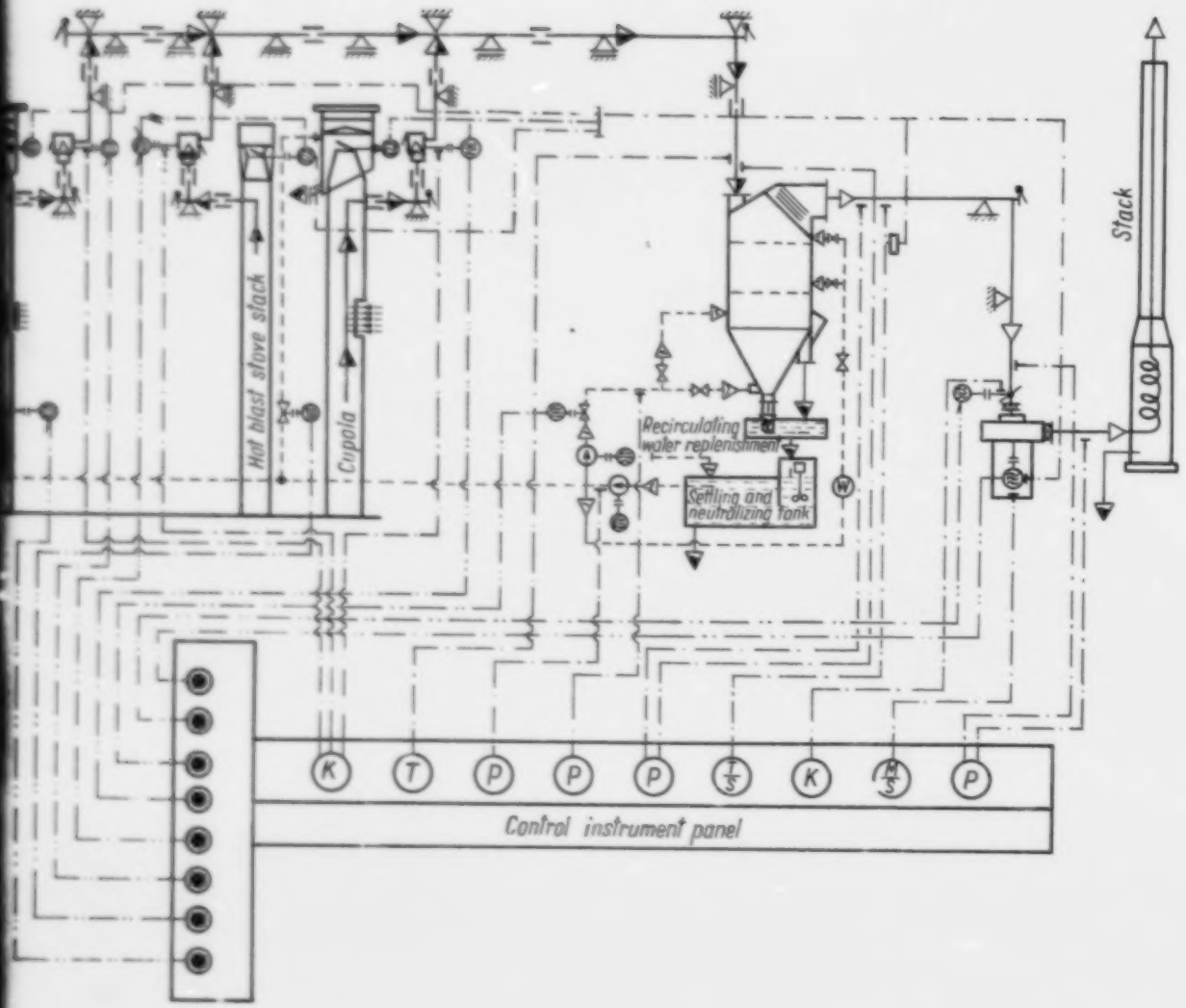

Fig. 4

with sludge; *4* — cleaned water; *5* — alarm signal; *6* — open-closed signalization; *7* — water flow gage; *8* — motor; *9* — closed position indicator; *18* — temperature gage; *19* — pressure gage; *20* — power consumption gage; *21* — explosion door; — movable bearing.

ance contacting scrubber (notation as in Fig. 3).

54.A

The system, whose diagram is shown in Fig. 3, is fully automatic and the only human attendance is the periodical inspection of the drives and of the control system. On the other hand, any breakdown or failure of the system bring about the automatic cutoff of the exhaust gases vented to the high-efficiency emission control devices with simultaneous automatic opening of the flap valves provided in the cupola hoods and of the valves in the water supply system for the rotary nozzles fitted in the hoods. Operation of this plant at a decreased power requirement by 30% will yield dust control index about 150 mg/m³. At the same time the efficiency is additionally impaired by 15–25%, if the exhaust gases treated are incompletely converted in the afterburner. For cupolas of the new design with elongated shaft, in which over 80% of the gases are vented to the heat exchanger, the use of high-efficiency emission control devices merely for treatment the heat exchanger gases was found satisfactory.

A control plant which embodies a medium-resistance contact scrubber is illustrated in Fig. 4. The principle of operation of the scrubber is based on the effect of inertia of the dust directed along with the gas jet from the nozzle onto the liquid surface, as well as on the effects of partial diffusion and coagulation due to enhanced contact and vigorous turbulence occurring on two grate plates provided.

The advantage of the device is that the gas pressure drop can be controlled, thus also the efficiency of the device can be varied over a definite range. The designed water consumption is 0.3–0.5 l/m³, circulation water requirement 2.5 l/m³, whereas the maximum pressure drop 550 kg/m³, and the control efficiency ranges 150 to 300 mg/m³ when the gases handled are featured by a low carbon monoxide content. The plant is of a simple and compact design and is small in size.

If the emission control is merely limited to the recuperator gases, efficiency and size of the plant are by 55% lower, and the prime cost is reduced by 40%, compared with the plant shown in Fig. 4. The capital and operating cost analysis for the cupola emission control plants based on the dry and wet techniques, performed at "Opam" Enterprise for the Polish conditions, has demonstrated a 2–5-fold higher cost for the fabric filter plants compared with the multistage control system with the use of Venturi tubes. The dust collection cost index instead depends upon the plant efficiency, i.e., upon the requirements as to the purity of the gas treated and upon the size of the cupolas themselves.

For wet collection systems this index ranges 2–5 zlotys per 1000 m³ of the exhaust gases treated. Hence it follows that emission control is often economically unsound for low-capacity cupolas because of a considerable share of the control costs in the production cost index. For that reason small cupolas of a capacity below 4 tons/hr should be gradually

phased out. Medium-size cupolas 5–15 tons/hr in capacity, exclusively hot blast operated, should be controlled by wet collection systems. In case the charge is conditioned before being fed to the cupola (scrap metal burning) application of fiber glass of teflon fabric filters is possible.

On the other hand, large-capacity cupolas in excess of 20 tons/hr which are exclusively hot blast operated should be controlled with Venturi-type wet collection devices or with wet electrical precipitators.

Conclusions

1. The cost analysis of a variety of methods of the cupola emission control shows a rather substantial effect of the emission control cost on the production cost for low-capacity (below 4 tons/hr) units. Hence, the elimination of small-size cupolas and their replacement by electric-arc furnaces appears reasonable.

2. Medium-capacity cupolas (5–15 tons/hr gray iron), because of enhanced particulate and gaseous emission rate, should be run only on hot blast. The recommended emission control system should be chosen from among the Venturi-type wet collection units. In case the charge is conditioned before fed to the cupola (by burning off the oil and other impuritis from the scrap metal) installation of fiber glass of teflon fabric filters is recommended.

3. A two- or three-stage wet system for cupola emission control ensures a high control efficiency. The dust concentration in the cleaned gases below 100 mg/m^3, and the SO_2 concentration below 200 mg/m^3.

4. In high-capacity cupolas (20–50 tons/hr) operated only on hot blast, when highest requirements as to the purification of the gases discharged are to be met, the emission control used should be of the Venturi tube type systems or wet electrical precipitators.

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Kwiecień, Z.

A DISK FEEDER FOR THE DUSTCLOUD GENERATOR

(Talerzowy dozownik pyłu)

A disk feeder of ingenious design is described with a coverage of the basic design features and a discussion of results of dust concentration measurements in a dustcloud produced in the generator which incorporates the feeder concerned. The device has been in operation for about four years.

A number of research projects in the field of air pollution control science necessitates the generation of a dustcloud of a definite dust concentration in the air or in any other gas. The dustcloud is produced in the apparatus referred to as dust feeders.

The dust feeders should have the following features:

— suitability for a wide variety of dusts,
— variable dust feeding rate,
— feeding rate control,
— constant dust concentration in the dustcloud produced.

One of the most ingenious designs of dust feeders are the disk types. The principle of operation of such feeders consists in pouring dust onto either a flat rotating disk or into a groove provided concentrically in the disk. The excess of dust beyond the groove or outside the definite stripe width on the flat disk is removed by a scraper. The dust stripe thus formed is sucked in by an ejector pump to generate a dustcloud as the disk revolves.

This paper covers a disk feeder for the dustcloud generator which has been in operation for four years to a full satisfaction.

Description of the Design

The dust feeder under consideration (Fig. 1) consists of a dust hopper, a disk with a groove driven with a motor, and an ejector pump that inspirates the dust from the groove and, at the same time, delivers the dust

into the dust duct or to another suitable site where a dustcloud is produced. The dust fed is contained in hopper *1* made of sheet steel shaped into a truncated cone connected to a cylinder. The hopper capacity is 2 to 3.5 kg depending on the kind of dust handled. The hopper bottom constitutes a grooved rotating disk *4*. The hopper is attached to the feeder body, like in the feeder due to Hattersley [1], by means of four-guide assembly which allows of a vertical motion of the feeder to vary the width of the slit through which the dust is fed. The dust coming out of the hopper is spread over the disk and into the groove by dust spreader *2*. The excess of dust outside the groove is removed by a scraper *3* into the excess dust container *5*. The spreader, in the form of a flat plate arranged

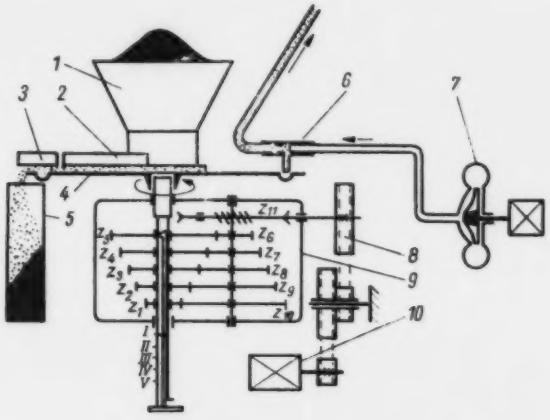

Fig. 1. Dust feeder: *1* — dust hopper; *2* — spreader; *3* — scraper; *4* — grooved disk; *5* — excess dust container; *6* — ejector pump; *7* — blower; *8* — V-belt gear; *9* — gearbox; *10* — motor.

tangentially to the cylindrical part of the hopper, is held against the disk by tension of a flat spring. Scraper is somewhat shorter than spreader and is arranged parallel to the former. Dust becomes inspirated from the groove and, subsequently, pumped into the duct to form a dustcloud.

The ejector pump, whose design is illustrated in Fig. 2, is connected to a blower — a household Alfa K-2 vacuum cleaner. The grooved disk is set in a rotary motion from a five-speed gearbox. The motor shaft drive is transmitted to the gearbox by means of a double V-belt transmission. There are five pairs of gears in the gearbox mounted on two shafts, i.e., on the driving and the driven shafts. All the gear pairs mesh permanently; those on the driving shaft are keyed in position, whereas the gears on the driven shaft are free to move. The driven shaft gears are wedged in place

by means of a sliding key depending on the ratio required. The power from the belt drive is imparted to the driving shaft through a worm gear. The grooved disk is mounted directly on the gearbox driven shaft. The

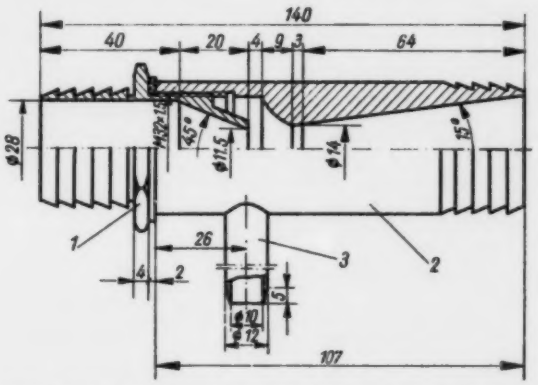

Fig. 2. Ejector pump that inspirates the dust from the groove of the feeding disk: *1* — nozzle; *2* — diffuser; *3* — suction tube.

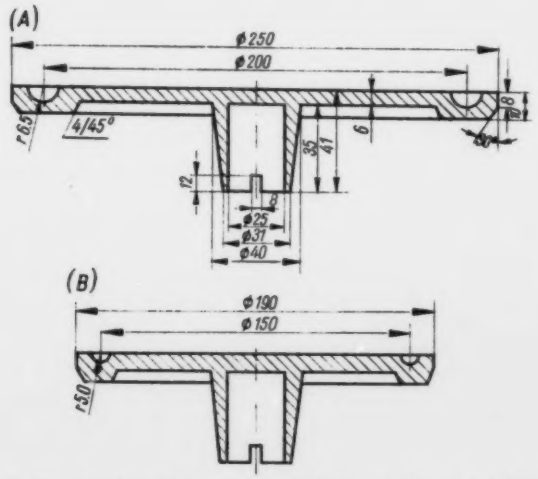

Fig. 3. The feeding disks: (*A*) — disk No. 1; (*B*) — disk No. 2.

quantity of dust fed by the feeder can be varied over a considerable range by the use of disks of a constant groove shape and size, and various virtual pitch diameter, or vice versa. Two of the feeding disks used in the feeder are illustrated in Fig. 3. General view of the dust feeder is shown on the photograph (Fig. 4).

Fig. 4. General view of the dust feeder.

Dust Concentration in the Dustcloud

The requisite dust concentration in the duct into which the dust is fed from the feeder can be found from relation

$$z = \frac{\pi^2 r^2 d_p \varrho_d n}{2(Q_1 + VF)} \tag{1}$$

where

z — the dust concentration in the duct, mg/m³,
r — the groove radius, cm,
d_p — the virtual pitch diameter of the groove, cm,
ϱ_d — the bulk density of the dust concerned, mg/cm³,
n — the disk speed, rev./sec,

Q_1 — the amount of the air pumped into the duct by the ejector pump, m^3/sec,

V — the air flow rate in the duct, m/sec,

F — the cross section of the duct, m^2.

As seen from consideration of relation (1) the dust concentration in the duct can be altered by varying the following variables:

(a) speed of the rotating disk,

(b) radius of the groove in the disk (cross section of the groove),

(c) virtual pitch diameter of the groove,

(d) air flow rate in the duct.

In the feeder in point the disks used had a groove of a round or V shape.

In case of disks with grooves of a little cross section (for instance, if the groove radius $r = 1$ mm), and when moist dust is involved, the flat-type spreader is inefficient in filling the groove up and an additional rotary spreader must be used. Such a rotary spreader can be made of a piece of rubber tubing suitably grooved and held against the surface of the feeding disk, and driven by an ML-2 laboratory stirrer.

To ensure correct operation of the feeder, a suitable slit has to be set between the dust hopper and the rotating disk. This can be done by means of an adjusting screw provided. The slit width affects the amount of dust coming from the hopper onto the disk. The amount of dust delivered by the hopper should be such that the disk groove be fully filled and as little of dust be removed to the container as possible. The preferable slit width ranges 3 to 5 mm.

Constant Dust Concentration in the Dustcloud

The constancy of the dust concentration in the dustcloud produced in the feeder is related to the uniformity of the dust feeding rate. This is one of the essential performance characteristic of the device of that kind. To determine this characteristic, measurements of the dust concentration in the duct were carried out in the duct into which dust was fed with the feeder. Dust was fed to a duct, which was in the form of a horizontal reinforced-concrete pipe of a circular cross section of a diameter of 1.2 m, in which the air was flowing at a constant rate of $V = 2.69$ m/sec. About 35 m away from the point where dust was fed and downstream the probe of a Casella model 112 A thermal diffusion dust analyzer was placed. A schematic diagram of the arrangement of the dust duct with the feeder and of the dust analyzer is provided in Fig. 5. The dust used in the tests was the coal dust from bed No. 510 of "General Zawadzki" Coal Mine, previously pulverized and screened through 200 mesh (75 μm). The specific

surface of the dust under test was $S = 11.140$ cm²/g, and its bulk density $\varrho_d = 530$ mg/cm³. The feeding was performed with the use of disk No. 1 (Fig. 3) rotating at a speed of $n = 0.025$ revolution per second. The samples

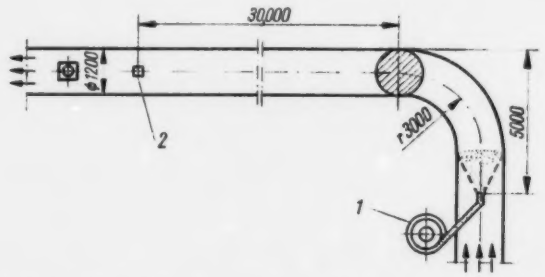

Fig. 5. The duct in which the concentration of the dustcloud produced by the feeder was tested: *1* — dust hopper; *2* — dust analyzer probe.

collected with the analyzer were counted using a Carl Zeiss model Polmi A microscope of a total magnification of 600 × with an eyepiece 15 × and an objective 40/0.65, of a resolving power of 0.4 μm. The dust particle count was made in the light field using a Cawood-Patterson reticle. As a sufficient concentration of dust in the samples was achieved after a 15-min collection, this period was taken throughout. The measurements were car-

Table

Results of the Dust Concentration Measurements in the Dustcloud Produced by the Feeder

Run No.	Dust concentration, particles/cm³		
	series I	series II	series III
1	4723	3851	4867
2	4471	4376	4473
3	4218	4551	4852
4	4117	4233	4174
5	4536	5327	4691
6	4349	4199	4055
7	4625	4704	4772
8	4215	4094	4898
9	4492	4930	4276
Mean S_n =	4416	4473	4673
σ =	0.1130	0.1572	0.1223
G_1 =	4854	5445	5108
G_2 =	3978	3501	4238

ried out within three days in a series of nine runs each day. The dust samples were collected at equal 30-min intervals. For each series of measurements standard deviation σ was evaluated, and the limits of the confidence interval, G_1 and G_2, were determined on a level $\alpha = 0.95$ (the Table).

It follows from the data reported that the values of dust concentration measured stay within the confidence interval assumed. The value of the standard deviation from the mean dust concentration for the measurements performed ranges from 0.1130 to 0.1572. Similar results were obtained by Hattersley who used the same type of dust feeder [2] and obtained the results with a standard deviation varying over the range of 0.07 to 0.1. Thus the dust feeder under discussion can be believed to generate a dustcloud of a sufficiently uniform dust concentration whose variations fail to exceed the common accuracy of measurements.

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DETERMINATION OF THE ORGANIC SOLVENT VAPORS IN THE AIR BY THE METHOD OF GAS CHROMATOGRAPHY

(Oznaczanie par rozpuszczalników organicznych w powietrzu metodą chromatografii gazowej)

Results of the experiments are reported which were carried out in relation to the application of the gas chromatographic technique in the analysis of organic solvent vapors in the air. Such vapors can be directly determined in the air by this technique from concentrations of 10 mg/m³. The method can be used in the monitoring of the atmospheric emissions.

Determination of minor quantities of vapors of organic solvents in the air is of considerable analytical importance in view of a wide industrial application of a great diversity of volatile organic compounds which exhibit an appreciable degree of toxicity.

Methods for the detection and quantitative determination of the solvents present in the air in minute quantities are described in the available literature. The methods can be broadly divided into chemical and instrumental ones. The first of the two classes includes the methods which involve absorption of the contaminants present in the air by passing a definite quantity of the air through a suitable absorbing reagent. The compounds absorbed can be analyzed quantitatively and qualitatively by means of suitable chemical reactions [1]. The other class embodies the techniques based upon certain physical properties of the compounds under analysis which can be measured using suitable instruments [2]–[4].

When gas chromatography technique is employed the operating conditions of the apparatus have to be established such as the column packing, column size, working temperature, and the flow rate of the carrier gas so as to achieve separation of the starting mixture into individual chemical entities. Then the individual compounds will be eluted from the column at different times since the injection of the sample. The retention times

thus obtained serve for a qualitative estimation of the mixture of chemical compounds concerned. The quantitative determination of individual compounds is accomplished by comparing the area contained under the elution bands [6]. The gas chromatography technique meets the requirements inherent in the analytical problem in point on account of a high sensitivity of the detectors, rapidity and facility in carrying out the analyses.

The subject of this study was the detectability of organic solvents in the air, specifically: alcohols (methyl and *n*-butyl alcohols), hydrocarbons (cyclohexane, toluene, and *m*-xylene), esters (methyl, ethyl, and *n*-butyl acetates), and ketones (cyclohexanone). The solvents mentioned have been selected because of their widespread use in the paint and varnish industry.

Experimental

Reagents

Analytical grade reagents supplied by the Chemical Reagent Factory in Gliwice were used in this investigation.

Conditions for the Chromatographic Analysis

The analyses were run on a Chrom 4, Laboratorni Pristroje, Czechoslovak gas chromatograph under the following operating conditions: 120 cm long 3-mm ID column packed with 80–100 mesh Chromosorb 101, from Applied Science Laboratories. The thermostat temperature 160°C. The vaporizer temperature 200°C. Sample volume 1 cm^3. The samples were injected with a gastight Hamilton syringe.

Argon purified with molecular sieves was used as carrier gas. The carrier gas flow rate was 40 ml/min. The hydrogen flame ionization detector was fed with hydrogen at a rate of 50 ml/min, and with air at a rate of 400 ml/min. The recorder chart speed was 1 cm/min. The area under the elution bands was calculated by multiplying the maximum band height by its half-width.

Preparation of the Standard Concentration of Organic Solvents in the Air

The standard concentrations of volatile solvents in the air were prepared by the method described in the literature, viz.:

— by static dilution of the solvent vapors in graduated vessels [7]–[9],

— by dynamic dilution of the vapors in diffusion vessels [10].

Static method. To prepare the standard reference mixtures of solvent vapors in the air, glass vessels of an exactly calibrated capacity of 1000 cm³ were prepared. The containers (Fig. 1) were stoppered with a silicone-

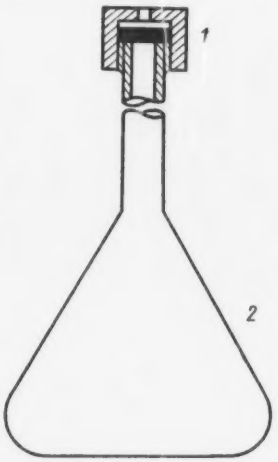

Fig. 1. The calibrated vessel for preparation of standard concentrations of solvent vapors in the air: *1* — silicone rubber seal; *2* — the calibrated glass vessel of capacity of 1000 cm³.

rubber membrane 3 mm thick. The standard concentrations were prepared as follows. The membrane of the vessel was punctured with an injection needle, the vessel was then evacuated using a rotary oil pump, and the

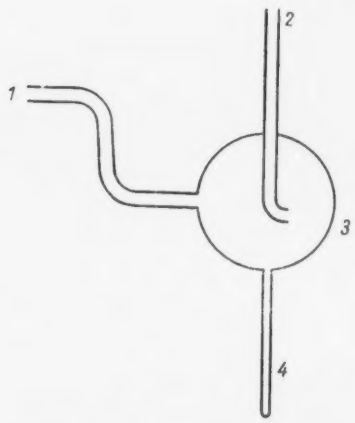

Fig. 2. The diffusion vessel for continuous preparation of standard concentrations of solvent vapors: *1* — air inlet; *2* — mixture outlet; *3* — diffusion vessel; *4* — calibrated capillary containing the solvent examined.

needle was removed. A definite quantity of the solvent was subsequently introduced using a Hamilton 1-μl microsyringe. Upon removal of the syringe the membrane was pierced with an injection needle to allow the air

to enter the vessel. Thus the contents of the vesel were mixed and the pressure inside the vessel was equalized with the outside atmospheric pressure. The amount of the solvent introduced into the first calibrated vessel was so matched as to make with the air contained in the vessel a mixture of a concentration 100-fold greater than the required one (ca 500–100 mg/m³ (STP)). The series of the standard concentrations was so obtained that upon equalizing of the pressure and mixing of the solvent vapors with the air in the first vessel, aliquots of 5 to 10 cm³ of the mixture were withdrawn from that vessel using a gastight syringe, and introduced into another calibrated vessel in which a partial vacuum was produced. Upon equalizing pressure in the other vessel, the concentrations of the solvent vapors in the air ranged 10 to 50 mg/m³ (STP).

Dynamic method. The alternative method of preparation of standard concentrations of the solvent in the air is the diffusion technique [11]. For each of the compounds analyzed diffusion vessels shown in Fig. 2 were calibrated. Accurate and reproducible dilution of the solvent vapors with air can be accomplished with the vessels used. The diffusion rate of solvent vapors through the capillary tube remains constant for a given vessel and a definite liquid under conditions of constant temperature and pressure. The diffusion rate is under the above conditions practically constant for a fairly long time. Therefore, constant concentrations of the solvents in the flowing air stream can be achieved over a period of several hours. It will be recognized that the dynamic technique yields higher accuracy in preparing the standard concentration, but it is much more laborious than the static method.

Discussion of Results

In Fig. 3 is shown a standard gas chromatogram of the compounds under analysis. Concentration of each component of the mixture under determination amounts to 50 ± 5 mg/m³ (STP). A satisfactory separation of the solvents has been achieved under the operating conditions specified previously. The detector signal for a definite compound analyzed, which is twice the noise level, is defined as the detectability limit of that compound [12]. Results of the determination of detectability limit for a number of solvent examined with the help of a Chrom 4 gas chromatograph equipped with a flame ionization detector are listed in the Table. The detectability limit depends on the shape of the chromatographic elution bands which, in turn, are related to the characteristics of the chromatographic system.

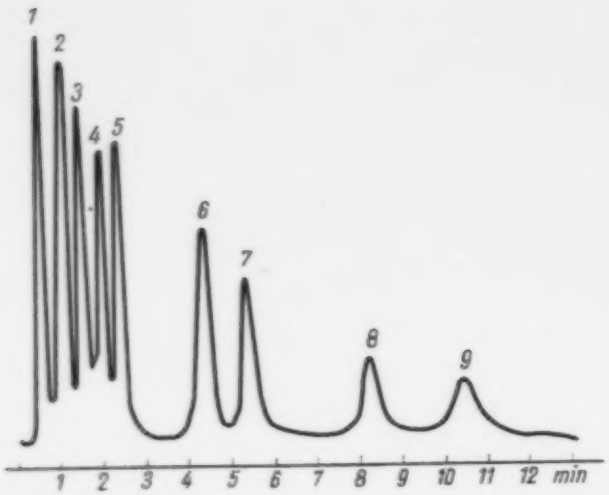

Fig. 3. A standard gas chromatogram of solvent vapors in the air; concentration of individual compounds 50±5 mg/m³ (STP); in the order of increasing retention time are: *1* — methanol; *2* — methyl acetate; *3* — ethyl acetate; *4* — n-butanol; *5* — cyclohexane; *6* — toluene; *7* — n-butyl acetate; *8* — m-xylene; *9* — cyclohexanone.

Table

Detectability of Solvents in the Air Using a Chrom 4 Gas Chromatograph

Solvent	Minimum detectable concentration in the air mg/m³(STP)
Methanol	0.5
n-Butanol	1.0
Cyclohexanone	10.0
Methyl acetate	1.0
Ethyl acetate	1.0
n-Butyl acetate	5.0
Cyclohexane	2.0
Toluene	2.5
m-Xylene	6.5

Conclusions

1. Organic solvent vapors in the air can be directly determined by the method described for concentrations $\geqslant$ 10 mg/m³.

2. Advantages of the method, over the absorption techniques, include lower sample size, short time of the analysis, and convenient procedure.

3. The analytical approach advanced here can be used in the estimation of the atmospheric pollution.

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Gregorczuk, M.

THERMAL POLLUTION IN THE UPPER-SILESIAN INDUSTRIAL REGION AND ITS CLIMATIC EFFECT

(Zanieczyszczenia termiczne w Górnośląskim Okręgu Przemysłowym i ich efekt klimatyczny)

The problem of thermal pollution over the Upper-Silesian Industrial Region and its share in the major components of the radiation balance is treated. On the basis of three-year monthly means of the air temperature for January and July from 28 weather stations on the Region and its periphery, attempts were made to determine the intensity and range of the heat island produced over the area of the Upper-Silesian conurbation. The monthly mean temperature differences between the towns of the Region and its peripheral out-of-town areas were found to be the most pronounced in the periods of impaired turbulence and air exchange (in the morning and evening), the value usually not exceeding 1.5°C.

Thermal pollution of the atmosphere and the hydrosphere, next to the particulate and gaseous emissions, is one of the essential factors impairing the balance in the biosphere. Emission of artificial heat is actually vanishing small in comparison with the amount of solar energy absorbed by the earth's surface, but expectedly with the maintained growth rate of power production the anthropogenic heat may become the reason for undesirable climatic changes in the coming century [2]. Although it follows from the stochastic model of climatic changes developed by Washington [15] that the climatological role of thermal pollution of the air will still be insignificant, however, this form of pollution over highly developed urban and industrial areas is one of the major factors responsible for the individual climatic character of these areas as compared with their surroundings [6], [13], [14].

Artificial heat can therefore come into play under urban and industrial conditions so that it is singled out as a separate item in the heat balance of the active layer which then assumes the form

$$R + S = P + LE + G$$

where

R — the radiation balance,

S — the total heat produced as a result of house heating, industrial operations, and from the means of transportation, designated by an arbitrary term of thermal pollution, or artificial heat or else anthropogenic heat, as opposed to natural heat forms occurring on the earth's surface without interference of man,

P — the heat given off by the active surface directly to the air or, occasionally, delivered to this surface from the air,

LE — the heat taken up for evaporation (transpiration) or liberated upon condensation of water vapor: L — the latent heat of vaporization or condensation, E — the vaporization (condensation) intensity,

G — the heat used up for the exchange between the surface of the active layer (soil, green cover, houses, squares, roads, and streets), and their deeper layers.

Thermal pollution affects each of the components mentioned, having thereby an effect on the conditions of convection, turbulence, evaporation, and radiative balance. The heated air layer produced over towns and industrial plants enhances the atmospheric back radiation, thereby decreasing the irradiation of heat from the earth's surface. The latter factor, next to the supply of heat from artificial sources, is also compensated for to some extent by increased absorption of solar radiation by the airborne particulates, which is equivalent to a reduced quantity of solar heat absorbed by the active surface.

The amount of artificial heat emitted equals one-third to one-sixth of the total solar radiation on the annual basis, as estimated for a few major European cities [1], [8]. Both the artificial heat and solar radiation exhibit a definite annual variation; in summer the heat of solar radiation considerably exceeds the amount of artificial heat, but in winter both quantities are close.

The reports from research done at the Climatological Department of the Institute of Geography of the Polish Academy of Sciences headed by Professor J. Paszyński [8], [10]–[12] give a certain insight into the question of the localization, range, and the annual variation of the heat balance components of the balance equation formulated above on the area of Poland (except for P term). The values of S calculated for the year 1965 amount to 0.2 kcal/cm^2 per year on the average in this country, which constitutes 0.25% of the annual total solar radiation and 0.50% of the total solar heat absorbed by the earth's surface. Over the urban and industrial agglomerations these figures are much higher. This is illustrated by the data of Table 1 where are entered ten cities of Poland of the highest emission of artificial heat. The data are supplemented with the figures refer-

ring to the inflow of total solar radiation into (Q), and to the irradiation from the earth's surface, designated as effective radiation (E), as well as with the ratios of totals of S to both these quantities. Of all the ten cities listed eight remain within the Upper-Silesian conurbation, and nine, in the Katowice Voivodship. Among the most industrialized six districts from the outside of the conurbation or rural ones, featured by an annual heat emis-

Table 1

Annual Totals of the Emission of Artificial Heat S, of the Total Solar Radiation Q, and of the Effective Radiation E, in kcal/cm², and the Percent Ratio of S to Q and E in Ten Industrial Cities of Poland in 1965 [8]

City	S	Q	E	S/Q	S/E
Chorzów	61.5	74.0	31.0	83.1	198.4
Świętochłowice	57.9	74.0	31.0	78.2	186.8
Wałbrzych	31.1	80.0	30.0	38.9	103.7
Bytom	29.1	75.0	31.0	38.8	93.9
Ruda Śląska	24.1	75.0	30.5	32.1	79.0
Częstochowa	22.1	80.0	29.6	27.6	74.7
Dąbrowa Górnicza	16.8	76.0	32.0	22.1	52.4
Zabrze	12.9	75.0	31.0	17.2	41.6
Gliwice	12.7	78.0	32.0	16.3	39.8
Będzin	9.9	75.0	30.5	13.3	32.7

Table 2

Annual Totals of the Emission of Artificial Heat S, kcal/cm², and Its Percent Ratio of the Annual Totals of the Emission of the Total Solar Radiation Q and of the Effective Radiation E in Five Nonurban Industrialized Districts of Poland in 1975 [8]

District	S	S/Q	S/E
Zgorzelec	2.75	3.39	9.07
Oświęcim	2.55	3.11	8.50
Będzin	2.50	3.34	7.72
Koźle	2.49	3.15	7.90
Wodzisław	2.32	2.93	7.72
Rybnik	2.08	2.67	6.52

sion rate of $S > 1.6$ kcal/cm² and S/Q ratio $> 2.1\%$ and $S/E > 5\%$ three districts are within the Katowice Voivodship and the remaining ones are in Wrocław, Opole, and Cracow voivodships (Table 2).

It can therefore be expected that the appreciable concentration of thermal polluters observed within the Upper-Silesian Industrial Region would give rise to heat islands over the congested urban and industrial areas.

One of the few available so far attempts to analyze the thermal relations in the Region is due to Kraujalis [7]. On the basis of thermograms and periodic observations from 1956, the authoress compared the 24-hr variation of air temperature at three stations located at the center of the Region (Świętochłowice, Lipiny, Chorzów) and at three stations situated outside the congested urban development (Gliwice, Rokitnica, Katowice). She also found that at the center of the Region both the extreme and the 24-hr mean temperatures are higher compared with the peripheral zone. The effect is the most pronounced in summer and is the least noticeable in winter.

In this paper an attempt was made to determine the spatial distribution of the air temperature over the area of Upper-Silesian Industrial Region and its peripheral zone. As the starting data use was made of the 24-hr means and the means of hours 7:00 a.m., 1:00 p.m., and 9:00 p.m. from 28 weather stations mostly of the third kind from the period 1957–1959, as in that three-year period there was the largest number of operating climatological stations on the area of the Upper-Silesian Industrial Region, and the observation data was the most complete. It will be noted that the maps of isotherms of the Region elaborated by Parchewski et al. [9] fail to account for the majority of the stations in that area such as: Gliwice, Bytom, Rokitnica, Lipiny, Świętochłowice, Chorzów, Sosnowiec, Dąbrowa Górnicza, or Niwka, which have had the observation period not coincident with years 1951–1960. The temperature distribution in the Region due to Zemła [16], although includes those stations, is based on the means from various observation years without reference to a common period.

All the stations covered in this study are located at distances greater than 1 km from the industrial pollution sources in the immediate neighborhood of greenery, which substantially impaired the influence of the city and the industry upon the thermal conditions there. Distribution of the temperatures obtained is presented in Figs. 1–6 in the form of isotherms.

In January (the coldest month in the three-year period concerned as well as in the "regular" period of years from 1881 to 1960) a characteristic temperature fall can be noticed when moving eastwards which in the strip St. Anna Mt. — Wolbrom (both stations are situated at the same altitude) amounts to 1.5°C/100 km.

The Upper-Silesian conurbation area in the period examined exhibits higher air temperatures than observed in the neighbor areas. There is no clear difference between the west and east parts of the area in point. The highest 24-hr mean temperatures occur in the northern part of the town of Świętochłowice (Lipiny) (cf. Fig. 1). This thermal privilege of the towns

Fig. 1. The 24-hr mean temperatures of January over the Upper-Silesian Industrial Region in years 1957–1959.

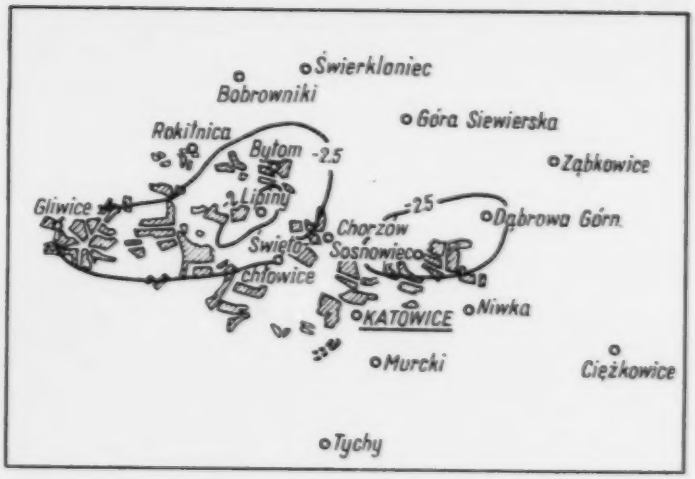

Fig. 2. The mean temperatures of January over the Upper-Silesian Industrial Region at 7:00 a.m. in years 1957–1959.

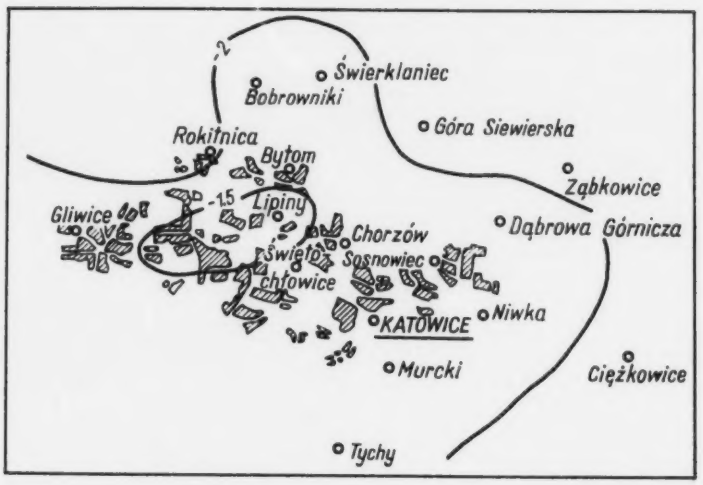

Fig. 3. The mean temperatures of January over the Upper-Silesian Industrial Region at 9:00 p.m. in years 1957–1959.

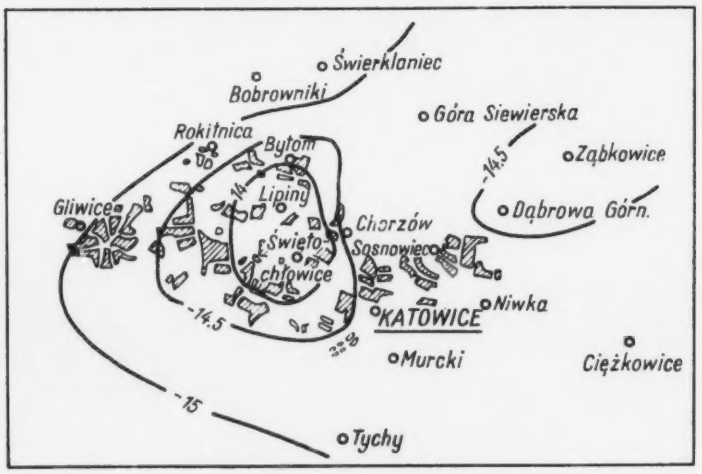

Fig. 4. The mean temperatures of February over the Upper-Silesian Industrial Region in 1956.

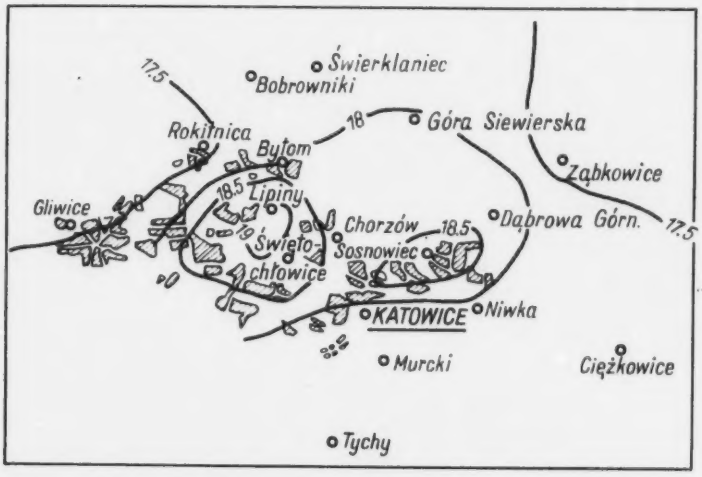

Fig. 5. The mean temperatures of July over the Upper-Silesian Industrial Region at 9:00 p.m. in years 1957–1959.

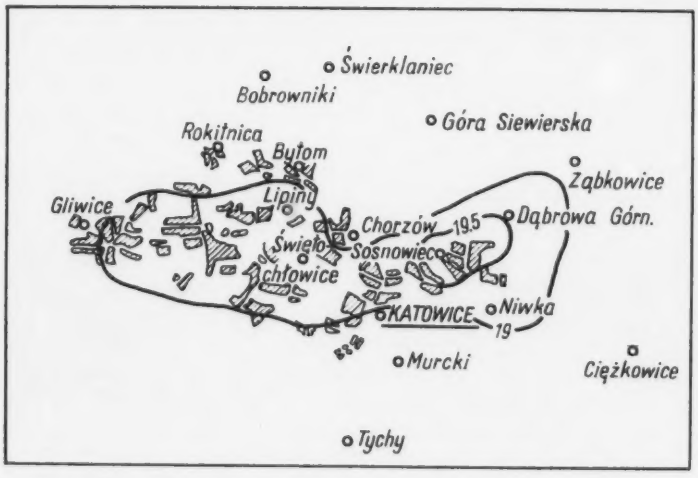

Fig. 6. The 24-hr mean temperatures of July over Upper-Silesian Industrial Region in years 1957–1959.

and cities of the Upper-Silesian Industrial Region is even more pronounced before sunrise (at 7:00 a.m., cf. Fig. 2) when the central portion of the urban agglomeration of the Region is warmer on the average by 1°C compared with the periphery. During the day the difference mentioned does not occur to appear again in the evening (at 9:00 p.m., cf. Fig. 3). The distribution of the 24-hr mean temperatures in February 1956 is shown additionally in Fig. 4. The month was, after [4], the coldest one in the past 45-year period (the second frostiest month since 1851). The elevated temperature area was the most marked in the central part of the conurbation of the Upper-Silesian Industrial Region. In the Świętochłowice–Lipiny zone the monthly mean temperatures were then by 2°C higher compared with the areas adjacent to the conurbation region.

In July (the warmest month) during the morning hours the thermal differences between the urban area of the Region and their peripheral area are actually unobservable, and at 1:00 p.m. the conurbation area is even on the average by 0.5°C colder than its periphery. In the evening instead (at 9:00 p.m., cf. Fig. 5) at the conurbation center the air temperatures are by 1.5°C higher on the average than on the periphery. The main temperature maximum occurs then in the northern part of the town of Świętochłowice (Lipiny), and the secondary maximum is noticed near Sosnowiec. The thermal privilege observed for the conurbation is also visible for the 24-hr mean temperatures (Fig. 6).

The monthly mean temperatures collected in this study over a period of several years demonstrate that the thermal differences between the stations of the Upper-Silesian conurbation and its adjacent areas are minute. The differences appreciably increase, however, during the radiation type weather (clear sky or moderate cover, soft wind or calm) to attain 6°C in the darkness hours and in the morning hours [7]. Analogous heat increments were observed by Tarajkowska [14] for the Częstochowa downtown and its outside-lying adjacent areas on the basis of her own data. The analogous differences found for the downtown of Warsaw [5] and of Cracow [3] were generally lower to attain on the average 1°C in the summer evenings.

Numerous investigations on the climate of a number of cities of the world have demonstrated that the heat rise observed for a large city reaches 10°C at most, being on the average in the range of values observed in the cities of Poland.

Conclusions

The climatological data hitherto obtained from the network of the State Hydrological and Meteorological Institute (now the Meteorological

and Water Economics Research Institute) stations allow to determine a very broad outline of the area of the thermal relations over the Upper-Silesian Industrial Region. The stations, now mostly nonexistent, were located at a considerable distance from the maximum thermal emission areas. Thus the data obtained from observations at those stations fail to give the actual picture of the thermal relations in the cities of the Upper-Silesian conurbation. Nevertheless, they point to the fact that in spells of impaired turbulence and air exchange during the evening and darkness hours the central regions of the Upper-Silesian conurbation exhibit higher temperatures compared with its adjacent areas.

The additional consumption of large quantities of heat for house heating in wintertime raises the air temperature on the average by 1°C in the morning and by 0.5°C during the remainder of the 24-hr period. On the other hand, in summertime the accumulation of solar heat absorbed by the material from which buildings and streets are constructed, combined with little heat losses for evaporation and transpiration, gives rise to a temperature increase in the center of the conurbation by ca 1.5°C compared with the out-of-town areas.

The figures determined are evidence of a relatively low range and of a minor climatological effect of thermal pollution of the atmosphere in the Upper-Silesian Industrial Region. The question, however, necessitates further investigation on the basis of a properly localized network of continuous air temperature and humidity recording stations. The measurements would have to be supplemented with the analysis of the air thermographic and satellite photographs.

Particularly essential in the investigation will be continuous monitoring of the horizontal and vertical range of the thermal pollution due to Katowice Metallurgical Plant which will be one of the major point sources of artificial heat in the world.

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Research on the TID Technique of SO_2 Removal from the Power Plant Exhausts in the People's Republic of Bulgaria

Within the COMECON project on problem IV. 1. of Comprehensive Development Project for the Techniques of the SO_2 Emission Reduction in the Gaseous Effluents take part Bulgaria, Poland, the USSR, the GDR Hungary, and Czechoslovakia.

In conformity with the information of the Bulgarian part, the preliminary studies conducted in Bulgaria on the so-called autoclave method of the sulfur dioxide removal from the electric power plant exhausts have proved economic unfeasibility of the method.

Much more promising appears to be the TID technique which is based on the absorption of sulfur dioxide in aqueous aniline. The technique has been developed by the research group from VKhTI in Sofia: Elenkov, D., Asenov, A., Mintsev, A., Tsotsev, V., and Petrov, P., headed by Professor Dr. Elenkov, D.

According to the principles of the technique, the exhaust gas containing SO_2 in the range 0.1 to 0.4% of a temperature 160–180°C is cooled down to a temperature ranging 56–58°C. Upon removal of particulate contaminants, the gas is made to pass through suitable absorbers (Venturi scrubbers, Peabody scrubbers, etc.). The absorbing liquor used is a 7% aqueous aniline solution.

In turn the SO_2 absorbed in the liquor is recovered by the desorption process, to be used in the sulfuric acid manufacture, and the aniline is recycled to the absorption process.

The test measurements carried out on a pilot plant of a capacity of 500 m^3 (STP) of gas per hour have confirmed the laboratory results.

A project has been launched in Bulgaria to construct a semi-industrial plant of a capacity of 50,000 m^3 (STP)/hr of exhaust gases for the "Marica-izotok-2" Power Plant, on which the TID technique will be examined and the requisite economic and engineering data will be gathered for a commercial project.

The information submitted by the Bulgarian part lacks in the data on the capital cost of the TID plant as well as on any estimates as to the operating cost. Furthermore, a number of doubts arise in the technological principles themselves which must have been solved or will have to be tackled by the originators of the TID plant project. The problems of greater significance include the following:

— the required dust extraction degree before the absorption process,

— a possible adverse effect of other gaseous contaminants present in the exhausts upon the liquid absorption process,

— the aniline losses in the desorption process,

— concentrating of the SO_2 recovered to the minimum 4% by volume required from the SO_2 fed to the sulfuric acid manufacture.

It will be recognized that the very idea of the use of solutions of amines (aniline is an aromatic amine) for the absorption of sulfur dioxide is sound.

A variety of scrubber types and catalytic afterburners for treatment gaseous effluents have recently aroused a renewed interest in their application for the removal of the contaminants right in their sources.

Scrubbers of diverse types are also used for treatment of natural and petroleum gases, hydrogen, and for desulfurization of liquid hydrocarbons. To give an example, Integral Industriebedarf-Gesellschaft mbH, Wien, which has a 50-year experience in the manufacture of the equipment for generation and purification of gases, offers ethanolamine scrubbers. In one type of the scrubber as absorbing liquors aqueous solutions of mono-, di-, or triethanolamine are employed. The absorption process is followed by the desorptive liberation of the sulfur compounds which are then burned in Claus sulfur burner.

The fact, that similar methods are in use in other countries for the removal and recovery of the exhaust gas contaminants (like in the previously mentioned Integral company) based on the absorption and desorption of gases in the amine solutions, makes one to believe that the Bulgarian specialists will soon be able to make the TID technique suitable for industrial application.

The operating cost of this method in the power plant is another story. Much more economically sound appears recovery of sulfur as elemental sulfur by Claus burner combustion than the recycling of the SO_2 recovered from desorption for the sulfuric acid manufacture suggested by the authors of the TID technique.

More detailed and more complete data from the large-scale testing will make the estimation of the TID technique feasible.

Prepared by S. Pietrus

An Exhaust and Ventilation System for Welders

At the Central Research Institute for Labor Protection in Warsaw an exhaust and ventilation device has been made. The device drastically improves working conditions at the welders' workplaces. The manufacturer of the device is the "Gliwent" Fan Works in Gliwice. The device ex-

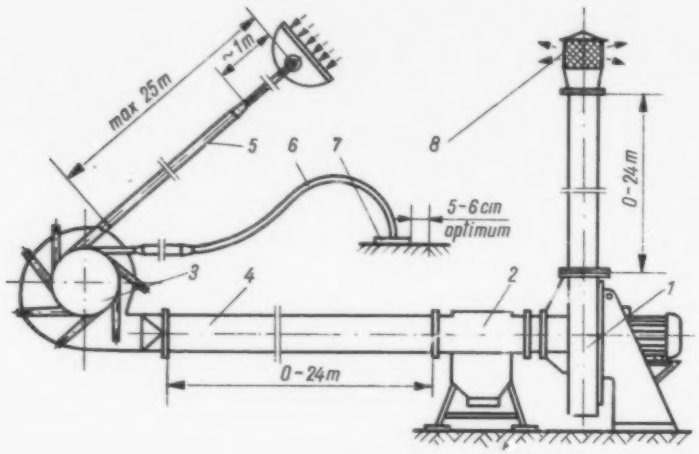


Fig. Schematic diagram of the IWO-8 exhaust and ventilation system: *1* — high-pressure exhauster; *2* — cinder bin; *3* — 8-way header; *4* — flexible duct; *5* — branched-off duct, ⌀ 56 mm; *6* — section of the duct, ⌀ 40 mm; *7* — suction cup; *8* — stack.

hausts the highly toxic welding contaminants as iron oxides, manganese oxides, and nitrogen oxides, and ensures the air purity at the work stands required by accepted standards. It is featured by modern and ingenious design, and its use affects work efficiency, among others, by the elimination of breaks previously needed to remove the accumulated dusts and gases. The IWO-8 exhaust and ventilation system is schematically illustrated in the figure.

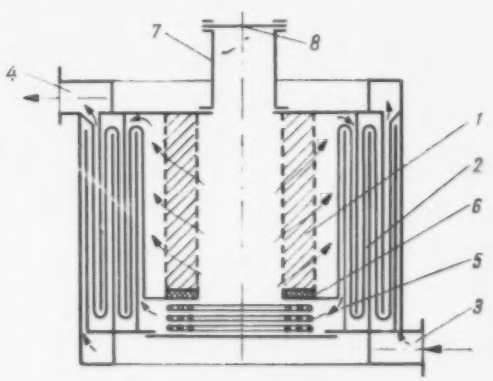
Prepared by J. K.

PATENT REVIEW

A Device for the Removal of Hydrocarbon Vapors from the Air

Inventors: B. Głowiak, P. Kabsch, A. Kukliński, J. D. Rutkowski
Patent owner: Technical University of Wrocław
Filed: December 6, 1971
Cl.: 12e, 3/01
Provisional patent No.: 74,369

The object of invention is a device for the purification of the air from hydrocarbon vapors in manufacturing plants, where hydrocarbon vapors evolve from the processes at the work stands. The device according to the invention consists of a catalytic converter *1* made in the shape of a cylinder accommodated coaxially in a number of metal cylinders which, combined with baffle plates, constitute a heat exchanger *2*. On the bottom of catalytic converter *1* an electric heater *5* is provided which is aimed to supply enough heat to initiate the combustion reaction. The air contami-



nated with hydrocarbon vapors is fed through inlet tube *3* through an annular slit into the inside of heat exchanger *2*, then passes by between its surfaces from which it warms up, to enter finally the inner space enclosed

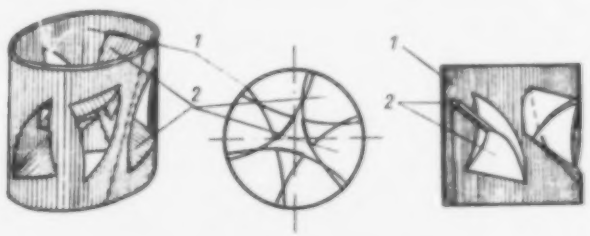
by converter. As the contaminated gas flows through converter, the contaminants contained in the gas undergo catalytic oxidation. The clean, heated from the combustion reaction, air passes again through heat exchanger where it is cooled down by giving off the heat through the walls to the dirty air, coming out by outlet tube *4*. Asbestos insulation *6* is provided at the bottom of converter to protect it from overheating. Pipe *7* sealed with thin aluminum sheet *8* constitutes explosion safety.

P. P.

A Packing Material for the Absorption, Distillation and Extraction Columns

Inventors: Z. Ziołkowski, J. Maćkowicz
Patent owner: Technical University of Wrocław
Filed: January 7, 1972
Cl.: 12e, 1/03
Provisional patent No.: 74,693

The object of invention is the packing material as used in particular in distillation, absorption, and extraction columns operating over a wide range of loads with gaseous and liquid phases. The element of the packing material, according to invention, constitutes a ring *1* formed by suitably shaping a parallel-side stripe of a suitable material, with oppositely arranged and bent inwards, spatially twisted guides *2* to form a section confined by curved, unattached to the ring sides, edges of various radii, and by the edge attached to the ring *1*, and inclined to the base of ring *1*. The vertexes of the adjacent guides *2* are not in mutual contact, and the sur-



faces of the guides form parallel helical surfaces. The operation of the packing material for the distillation, absorption, and extraction columns consists in that the liquid drops flowing down inside ring *1* come across

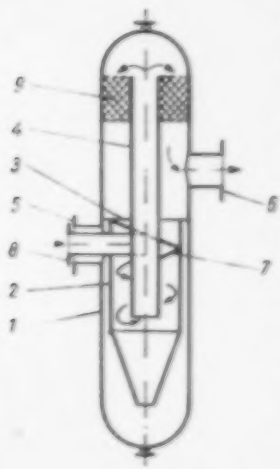
guide *2*, and drip from it onto the upper surface of the opposite and adjacent guide *2*, and flow over onto the outer surface of the ring. In case the liquid flows over the outer side of ring *1*, held by the adhesive forces, it flows over the bottom surface of guide *2* toward its vertex, wherefrom it drips onto the upper surface of the adjacent guide *2* and flows outwards over that guide onto the outside of the ring. The design of the packing material always ensures the outflow of liquid incoming from the inside of ring *1* as well as that from its outer surface inwards, whereby the channeling effect can be avoided with the elimination of otherwise dead and nonfed with the liquid spaces within the packing.

P.P.

Cyclone Dust Collector for Natural Gas

Inventors: W. Duliński, R. Staszewski, S. Biber
Patent owner: Academy of Mining and Metallurgy, Cracow
Filed: October 13, 1971
Cl.: 12e, 3/01
Provisional patent No.: 74,153

The object of invention is a cyclone dust collector for cleaning of natural gas, used in oil drilling for collection of solid bedrock and liquid particles from natural gas, to be provided directly on the borehole. The object of invention accommodated in the lower section of the body *1* cyclone *2* separated from the upper section with a horizontal partition *3* provided with a through tube *4* connecting its lower section with the upper one. The body *1* is provided with a fixed outlet tube *6* in the upper section and above horizontal partition *3*. In the upper cyclone *2* section at the height of the fixed inlet tube *5* guide vane *7* is attached. Fixed inlet tube *5* accommodates an exchangeable tube *8* whose inside diameter is selected according to the operational parameters of the gas handled. The section of the body *1* over the outlet tube *6* is separated from the space of the body *1* over the partition *3*, with a filter cartridge *9*, and is connected to the lower section of the body *1* with the through tube *4*. Under



operating conditions the cyclone dust collector is equipped with the exchangeable tube *8* which is inserted into the fixed inlet tube *5*, and diameter of tube *8* is selected in accordance with the operational parameters of the gas handled. During exploitation of the natural gas field, when the pressure and the rate of the gas taken drop, which results in decreased overall efficiency of the cyclone collector, the exchangeable tube *8* used previously is replaced by another one of a smaller diameter.

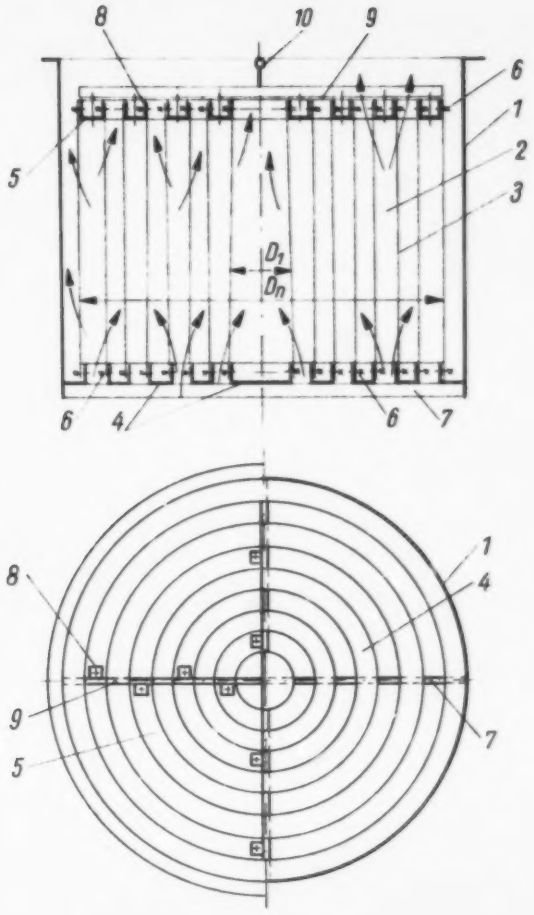
P.P.

Multisectional Fabric Filter

Inventor: A. Wyrwała
Patent owner: "Bipromet" Nonferrous Metals Industry Designing Office, Katowice
Filed: December 4, 1972
Cl.: 50e, 5/01
Provisional patent No.: 74,056

The object of invention is a multisectional fabric filter designed for dry cleaning of gases. The filter is used as a single unit or as a unit of multichamber filterhouse. The filter consists of housing *1* which accommodates sections *2* of varying diameters from D_1 to D_4 and constituting fabric filter bags *3*, and bottom mounting thimbles *4* and top thimbles *5*, to which bags *3* are fastened with clamps *6*. Bottom thimbles *4* are supported on the bottom crosshead *7*, and top thimbles *5* are bolted with screws *8* to top crosshead *9* mechanically coupled with the shaking mechanism *10*. The dust-laden gas, that is supplied to the filter by suction or blowing, passes from the bottom between thimbles *4* to the space between the adjacent bags *3*, then upon permeating bags it enters the outlet space passing between top thimbles *5*. The precipitated dust settles on the bags *3*, from which it is dislodged by means of shaking mechanism *10*.

P.P.

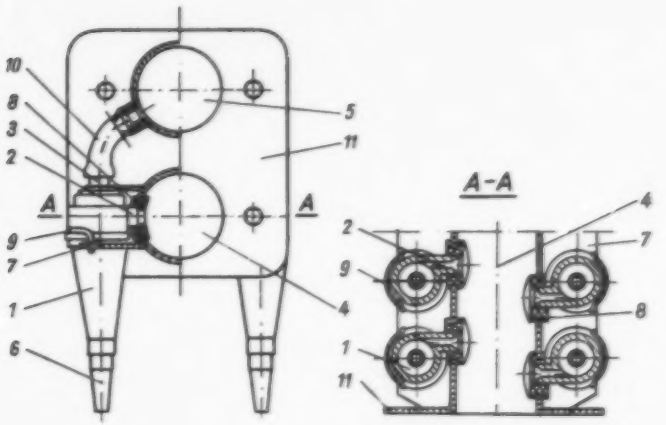


Multihydrocyclone

Inventor: S. Bednarski
Patent owner: "Cebea" Research and Develcpment Center of the Chemical Equipment Construction Industry, Cracow
Filed: August 23, 1971
Cl.: 12d, 1/01
No.: 70,777

The object of invention is a multihydrocyclone designed to be connected into single- or multistage batteries. Individual hydrocyclones *1* in-

corporated into the multihydrocyclone are attached with their inlet nozzles *2* to feed chamber *4*, whereas weir tubes *3* of hydrocyclones *1* are connected with weir chamber *5* positioned preferably parallel to and above feed chamber *4*. Discharge nozzles *6* of hydrocyclones *1* are placed over the open from the top (shown in the figure) discharge tank. Feed chamber *4* is provided with horizontal parallel ribs *7* which run along the entire length of the chamber *4* walls. The ribs *7* have openings cut to accommodate hydrocyclones *1*. In the feed chamber *4* walls, between the rib *7*



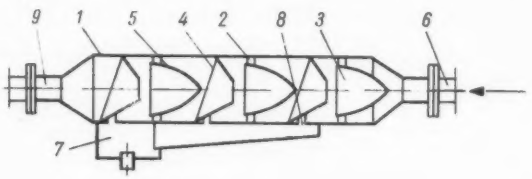
pairs, holes are provided in which flexible collars *8* are fitted to connect hydrocyclones *1* by means of their inlet nozzles *2*. Horizontal ribs *7* possess fastening holes for swivel clamps *9* which secure hydrocyclones *1* in position and prevent them from being forced out by the liquid delivered under a positive pressure to feed chamber *4*. Weir tubes *3* of hydrocyclones *1* are joined to weir chamber *5* detachably, e.g., by means of flexible hoses *10*. Both chambers, the feed one *4* and weir chamber *5*, are mutually fixed by at least two sheet-metal mounting plates *11* provided at the chamber ends. The outer faces of plates *11* serve as flanges designed for connecting individual multihydrocyclones to the feed and discharge lines not shown in the figure, and for plugging the openings *4* and *5* which are temporarily taken out of service. The faces can be used, if desired, for heading connection of two or more multihydrocyclones into batteries.

P.P.

Multistage Vapor Eliminator for Gas Cleaning Particularly for Compressed Air

Inventor: A. Wieczorek
Patent owner: "Ryfama" Rybnik Machine Works, Rybnik
Filed: March 12, 1970
Cl.: 12e, 3/01
No.: 71,245

The object of invention is a multistage vapor eliminator for gases, especially, for cleaning compressed air from suspended liquids. The vapor eliminator consists of jacket *1* which accommodates deflecting baffles *3* which are held in position on space ring elements *2*, and cones *4* welded directly to jacket *1* and inclined to the eliminator axis at an angle of 20°. The area of the ringlike surface *5* formed between jacket *1* and baffle *3* corresponds to the cross section area of pipeline *6*. In the bottom section of the horizontally arranged eliminator tank *7* is provided, from which the collected liquid is discharged by means of recognized devices. The liquid drops enter tank *7* through openings *8* provided in jacket *1*. The



eliminator has tube *9* designed for direct fastening of the unit to pipeline *6*. The eliminator described operates as follows. The gas flow must coincide with the direction marked with an arrow. Its working position in the solution provided for illustration is horizontal one. However, the eliminator can be operated vertically upon suitable adaptation of tank *7* for such conditions. The gas entering the eliminator is deflected by means of baffle *3* toward jacket *1*, where it subsequently impinges on cone *4* that rapidly turns away the direction of the stream flow. The liquid particles heavier than gas settle on cone *4*, then under gravity they enter the negative pressure zone at the site cone *4* is joined to jacket *1*. Owing to the inclination of cones *4* in the direction coincident with the vapor-laden gas the liquid settled flows down to openings *8*, thence continuously to tank *7*. The gas thus cleaned subsequently passes into next vapor eliminating chamber, where further precipitation of mist occurs. The overall vapor extraction degree of the gas conveyed through the pipeline, especially of

compressed air, depends upon the number of successive chambers provided in the design.

P.P.

Method for Preparation of an Agent for Purification of Gases from Sulfur Compounds

Inventor: B. Kubica
Patent owner: "Oświęcim" Chemical Plant
Filed: October 26, 1970
Cl.: 26d, 8/04
No.: 71,907

The object of invention is a method for preparation of an agent for purification of gases from sulfur compounds such as hydrogen sulfide and organic sulfur compounds. The method developed for the preparation of the agent for the removal of sulfur compounds from gases consists in mixing the material containing alfa-Fe_2O_3 with alkaline components such as $Ca(OH_2)$, NaOH, or Na_2CO_3, homogenization of the resultant mixture, shaping the paste into desirable form, and drying. As the alfa-Fe_2O_3 containing material an upgraded synthetic mineral is used, which contains alfa-Fe_2O_3 of hexagonal structure, and active compounds of aluminum, silicon, and magnesium, and calcium hydroxide is taken in a quantity 5–4% of dry weight, and sodium carbonate or hydroxide used constitutes 5–30% dry weight, and the drying temperature is 250°C. The drying is carried out at about 250°C in a hot stream air or other gases. The agent is pelletized into grains 3–5 mm in diameter.

P.P.

NEWS IN BRIEF

Advanced Training of Brainpower

The Technical Press Council, which is advisory and consultative body of the Ministry of Science, Higher Education and Technology and of the National Organization of Technicians, has stated that specialist press continues to be the overriding vehicle of technological know-how and advance. It has the following goals to fulfil:

— continuous educating and advanced training of brainpower,

— popularization of technological science among the general public,

— advertisement of the achievements of the Polish science and economy abroad,

— the shaping and consolidation of the consciousness of the union of brainpower with the working class.

Every technical journal should fully meet not only the current but also the coming needs of technology, and the technical press should include within its scope of subjects covered all the branches of technology of importance for national economy to form an integrated and coordinated and, at the same time, plan-operated tool of the struggle for technological and economic progress. The sponsoring the development of technical journals has been a fundamental task of the program of the National Organization of Technicians and of the scientific and engineering associations incorporated in this organization.

The advance of technology and expansion of production call for an accelerated development of technical press, increased value of the contents reported in the journals, a full correlation of the problems taken up on its columns and an efficient way of their solution, and as such it should have guaranteed conditions for its full development. The development of technical press requires the following:

— continued improvement as to the usefulness of technical press in professional work of engineers and technicians by enrichment of the contents and improved subject planning of the journals;

— provision of the press with organizational conditions and requisite funds for its activity and development;

— more rapid availability of scientific and technical information to the reader, and its widespread popularization combined with an active use of the press by engineers, technicians, and skilled workers, as the press should be considered the source of knowledge and the place for exchange of experience and professional achievements;

— continued work on forecasting, editing and publishing, popularization, and reading habit surveying of technical press.

Of particular importance for the development of technical press the following activities must be mentioned:

— further consistent effort aimed at straightening up the status in the field of technical periodicals;

— more allocations than up to now for the development of the professional-journalistic type periodicals published by specialized publishing companies;

— bringing into existence new periodicals requisite for the national economy in the fields insufficiently covered or not covered at all, or else not edited to date on the adequate scientific and technical level;

— improvement of the organizational structure of the publishing enterprise of the National Organization of Technicians on the basis of novel organizational models which ensure a permanent and vivid link of the technical press with the association's movement;

— stronger emphasis on the activities of the scientific and technical organizations and their organizational units on the active advertisement and popularization of the reading habit and on the ability to use technical press;

— development and implementation of the proper forms of organization of the reading of technical press in workplaces as to both the number, subject range of the periodicals subscribed to, and their circulation;

— taking into consideration the literary output in technical periodicals and the editor's positions held by engineers and technicians in their qualifying, promotions and professional awards;

— creation of a center which would initiate and coordinate work on specialized terminology in all branches of technology and would cooperate with the Scientific and Technical Terminology Committees and with pertinent technical periodicals both in the formation and dissemination of this terminology.

J.K.

Environment Protection 75 Workshop

On April 3 till June 19, 1975 the Silesian Technical University in Gliwice organized Environment Protection 75 workshop. The subjects covered include:

— Selected Problems from the Natural Environment Protection and Engineering in the Katowice Voivodship — S. Kiermaszek;

— National Parks of the World — the Treasury of Our Civilization — Professor Dr. S. Myczkowski;

— The Results of Changed Natural Environment in the Industrial Regions — Professor Dr. J. Paluch;

— The Biology of Waters and the Economy of Man — Professor Dr. K. Starmach;

— Tourism and the Protection of Nature — Dr. A. Leńkowa;

— The Environmental Designing — Docent Dr. T. Gawłowski;

— The Building Protection over the Mining Areas — Docent Dr. H. Przybyła;

— The Environment Protection in the New Water Law — Dr. K. Podgórski;

— The Quality of Atmospheric Air in the Katowice Voivodship — Forecasts till 1990 — Professor Dr. S. Jarzębski;

— Reconstruction of Landscape for Recreation Purposes on the Example of the Voivodship Culture and Recreation Park and of the Forest Shelterbelt — M. Sc. J. Szczepańska.

J.K.

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